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THE MAYFLY (EPHEMEROPTERA) AND STONEFLY (PLECOPTERA) FAUNA OF A FOOTHILLS STREAM IN ALBERTA, WITH SPECIAL REFERENCE TO SAMPLING TECHNIQUES

BY

© CAROLYN [illegible]

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF ZOOLOGY

EDMONTON, ALBERTA

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(C) Kenneth A. Zelt

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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Mayfly (Ephemeroptera) and Stonefly (Plecoptera) Fauna of a Foothills Stream in Alberta, with Special Reference to Sampling Techniques" submitted by Kenneth Arthur Zelt in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The physical, chemical and biological features of a foothill stream of western Alberta were investigated during the period May 1967 to July 1968 with the hope that information collected would provide a basis for documenting the effects of future pulpwood extraction on the stream community.

Water discharge and water temperature of Wampus Creek exhibited extensive annual fluctuations. Increased discharge and slowly rising temperatures occurred during the spring. In summer, daily temperatures fluctuated widely and discharge decreased. Water temperatures were continuously above 15°C for only one week of the study. By late August, water temperatures were steadily decreasing. Flow reached low stages during the fall and remained low throughout the winter.

During the study period, 14 species of Ephemeroptera, 25 species of Plecoptera, 14 species of Trichoptera, and representatives of six families of Diptera were collected. Life histories were worked out for the common species of mayflies and stoneflies. *Ephemerella doddsi*, *Ephemerella grandis ingens*, *Ephemerella coloradensis*, *Ephemerella tibialis*, *Ephemerella inermis*, *Epeorus longimanus*, *Rhithrogena* sp., *Nemoura cinctipes*, *Nemoura oregonensis*, *Nemoura decepta*, *Brachyptera nigripennis*, *Isogenus nonus*, and *Arcynopteryx curvata* were univoltine; *Baetis* sp. had at least two generations a year; *Acroneuria pacifica* required more than one year for development. *Ephemerella tibialis* possibly was a true summer (temporary) species.

Ephemeroptera, specifically *Baetis* sp. and *Cinygmula* spp., was the dominant order of aquatic invertebrates of Wampus Creek in terms of

numbers and volume-biomass. For most of the year, mayflies made up at least 50% of the "total" fauna. Plecoptera was the second most important order of aquatic insects.

Quantitative samples, collected with the Surber sampler, indicated that Wampus Creek had a yearly average of 190 organisms per ft^2 ($2047/m^2$) and a yearly average volume of 0.33 cc per ft^2 ($3.55\ cc/m^2$).

Statistical differences in life history analysis due to mesh size efficiency were found for *Ephemerella doddsi* and *Nemoura decepta*. Mesh size differences did not statistically influence life history interpretations of *Epeorus longimanus*, *Nemoura cinctipes*, *Nemoura oregonensis*, and *Brachyptera nigripennis*. Body shape of aquatic organisms appeared to be important in explaining mesh efficiency. Number and volume-biomasses, expressed in percentages, collected by different meshed dip nets were similar. Samples were also collected with a "composite" dip net and a "composite" Surber sampler, each having both regular and fine meshed nets. The fine net component collected a much larger number of organisms than did the regular net component, but differences in terms of volume-biomass were small.

ACKNOWLEDGMENTS

I would like to express my thanks to Dr. H.F. Clifford for his guidance and supervision on this study, and for critically reviewing the manuscript. Likewise, I would like to thank G. Haugen who initiated the Tri-Creek Fisheries Watershed Investigation and stimulated my interest in working on this project. Thanks are due to M.E. Pinsent for his advice and assistance in obtaining the winter samples.

The Alberta Department of Lands and Forests provided financial support and equipment during the summer of 1967 for which thanks are due to M.J. Paetz.

Dr. R.K. Allen and Dr. R. Hartland-Rowe identified certain Ephemeroptera; Dr. W.E. Ricker and Dr. A. Nebeker identified the Plecoptera; and Mr. A. Nimmo identified the Trichoptera. Dr. S. Zalik provided advice on the statistical analysis of the data. To these people I express my sincere gratitude.

For their advice and criticisms I would like to mention D. Buchwald, G. Daborn and K. Horkan.

To my wife, Wendy, I am particularly indebted both for her patience and encouragement and for her assistance in the preparation of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Man's activities have in many cases altered the ecological equilibrium of stream communities. Specifically, logging, road and bridge construction, stream-channel relocation, and removal of vegetation along stream banks have resulted in drastic changes in stream communities. Unfortunately, aquatic ecologists, in most cases, have failed to document these physical, chemical, and biological changes. Documented information on the effects of land use as related to stream communities could have a dual purpose. Firstly, this information would enable ecologists to better understand the dynamic relationship between the biological community and the physical and chemical features of the aquatic environment. Secondly, it would be of great practical benefit to fisheries biologists, who have often had to formulate policies from data collected after habitat destruction had occurred. The results of adverse land-use activities are obvious; however, little concrete data are available that can demonstrate what actually happened to the stream community. Since land manipulation will continue and the number of virgin streams is rapidly decreasing, it is imperative that an ecological study involving many disciplines be designed to document these changes.

Situated along the eastern foothills of the Rocky Mountains are many small watersheds that are important sources of water for some of the major river systems of western and northern Canada. Many of these watersheds are forested with pine and spruce, prime raw materials for the pulpwood industry. In 1965, the Tri-Creek Fisheries Watershed Investigation was initiated for the purpose of measuring and recording the effects of land use, pulpwood extraction and its associated activities

on the physical, chemical and biotic characteristics of three small trout streams of western Alberta. Co-operating in this investigation are agrologists, biologists, foresters, geologists and hydrologists.

My association with this investigation was to study the aquatic invertebrate fauna, and thus provide a foundation for studies to be carried out during and after pulpwood extraction. The main objectives were as follows:

1) to determine what species were present,

2) to describe the life histories of the common species,

3) to describe the community structure, and

4) to determine the standing crop of the aquatic invertebrates.

To achieve these objectives, the problem of sampling required special consideration. Macan (1958*a*) reviewed the various methods of sampling bottom fauna in stony streams. After examining the advantages and disadvantages of the various methods, I decided that the hand-net method would be used for obtaining information on the species present, life histories and community composition. For standing crop determinations, the Surber sampler was selected as the most appropriate for the study area.

The importance of mesh size in sampling an aquatic community has received some discussion by ecologists (Jônasson, 1955; Macan, 1958*a*; Mackereth, 1957); however, no studies have been carried out in which samples collected with a fine meshed sampler are compared with those of a coarse meshed sampler in relation to the life histories of the organisms, community composition (numbers or volume-biomass) and standing crop. The importance of mesh size as related to life histories, community composition and standing crop was assessed using different

samplers: dip nets and Surber samplers constructed with either fine or coarse meshed nets, and "composite" samplers having both fine and coarse meshed nets.

DESCRIPTION OF STUDY AREA

The Tri-Creek basin, consisting of Wampus, Deerlick, and Eunice Creek, is located approximately 100 km west southwest of Edmonton, Alberta (Fig. 1). The geographical location is 53°09' north latitude and 117°15' west longitude. The three northward flowing streams are tributaries to the McLeod River, a tributary of the Athabasca River, which drains into the Arctic Ocean via the MacKenzie River.

The basin is situated in the Rocky Mountain Foothill Belt, an area characterized by ridges and valleys orientated in a northwest direction. Range elevations are 1,259 to 1,685 metres above sea level. Geologically, rocks of the Upper Cretaceous Alberta Group and Brazeau Formation are represented; surficial materials in the basin include glacial tills, glaciolacustrine silts, local ice contact and deltaic deposits, and a minor glacial outwash (Currie, 1969). Soils are mainly bisequa grey wooded in association with orthic grey wooded soils, the latter occurring in areas having glacial till as the parent material (Currie, 1969). Moss (1955) classified the vegetation of the study area as sub-alpine forest dominated by coniferous vegetation. Dominant tree types are lodgepole pine *(Pinus contorta)*, white spruce *(Picea glauca)*, black spruce *(Picea mariana)*, and alpine fir *(Abies lasiocarpa)*. Meadows of willows *(Salix* spp.), sedges *(Carex* spp.), and swamp birch *(Betula pumila)* occur in areas of moist soil.

The climate of the study area is classified as humid microthermal and subarctic (Atlas of Canada, 1957). The Köppen classification indicates a rain-snow climate with cold winters, precipitation throughout the year, and cool, short summers, having mean temperatures above 10°C for only 1 to 3 months.

Fig. 1. Map of the study area.

Symbols: A Hydrometric station, artificial control

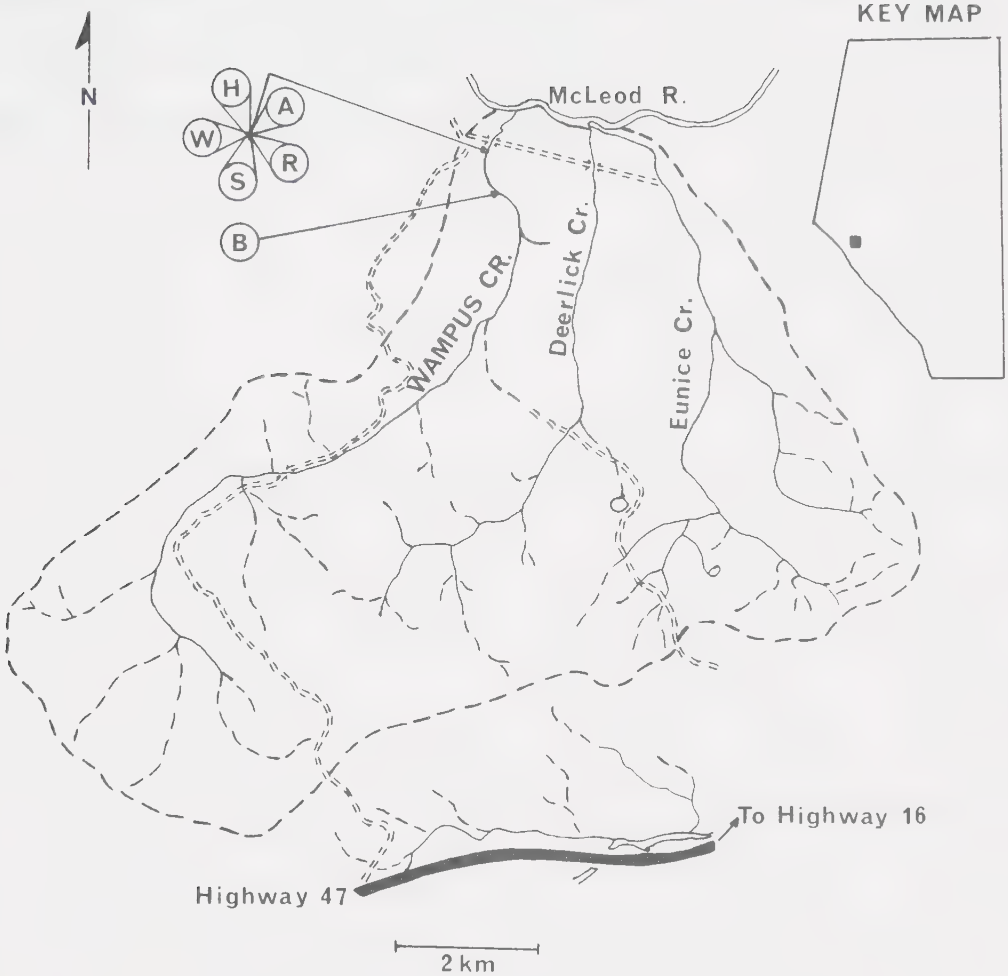
B Biological station

H Hygrothermograph

R Rain gauge

S Sedimentation station

W Water thermograph



KEY MAP
N
H
A
W
R
S
B
McLeod R.
WAMPUS CR.
Deerlick Cr.
Eunice Cr.
To Highway 16
Highway 47
2 km

A meterological station located in the study area provided the precipitation and temperature data of Table 1. Total precipitation for the period June 1967 to June 1968 was 40.34 cm. The mean annual total precipitation for this area is 50-75 cm, indicating that the study was conducted during a rather dry year. A maximum daily temperature of 17.8°C in February 1968 was unusual for this time of year.

Wampus Creek supports a fish fauna composed of rainbow trout *(Salmo gairdneri)*, mountain whitefish *(Prosopium williamsoni)*, burbot *(Lota lota)* and spoonhead sculpin *(Cottus ricei)*.

TABLE 1. Air temperatures and precipitation at Wampus Creek, June 1967 to June 1968

Month	*Air Temperature (°C)* Mean Daily	Mean Daily Maximum	Mean Daily Minimum	Maximum Daily	Minimum Daily	Total Monthly Precipitation cm	inches	
1967								
June	10.3	18.6	1.9	26.6	-2.8	7.90	3.11	
July	11.4	20.8	2.1	28.3	-2.8	5.10	2.01	
Aug.	13.0	23.3	2.6	30.0	-5.0	4.17	1.64	
Sept.	10.3	21.0	-0.3	29.4	-5.6	1.93	0.76	
Oct.	0.8	7.1	-5.6	16.1	-14.4	1.83	0.72	
						0.51	0.20	s
Nov.	-5.9	1.5	-13.4	10.0	-25.0	3.40	1.34	
						3.05	1.20	s
Dec.	-12.9	-7.1	-18.8	3.9	-37.8	1.19	0.47	s
1968								
Jan.	-15.0	-8.7	-21.3	12.8	-35.5	3.56	1.40	s
Feb.	-12.7	-2.6	-22.8	17.8	-44.4	0.51	0.20	s
March	-3.8	3.5	-11.1	13.9	-17.8	1.14	0.45	s
April	-3.0	5.8	-11.8	15.0	-24.4	5.84	2.30	s
May	4.0	11.9	-4.0	21.6	-8.9	3.78	1.49	
						1.14	0.45	s
June	7.4	15.2	-0.4	23.3	-5.0	3.28	1.29	

s — Precipitation as snow.

METHODS

Physical and chemical

Stream discharge was obtained from an artificial gauging well connected by an outlet pipe to a broad crested weir constructed across the width of Wampus Creek (Fig. 1). Changes in water level in the artificial well were recorded with a Leopold Stevens A-35 negative spring drive recorder. Water level data were converted to cfs by the Department of Energy, Mines and Resources, Inland Waters Branch.

At 3 day intervals during the spring and weekly during the summer, two suspended sediment samples were taken using a DH-4 sampler. The sampler consisted of a holding rod attached to a torpedo-shaped head containing a sample bottle. Water entered the bottle through a calibrated nozzle. A sample was collected by lowering the sampler at a constant rate from the surface to the bottom and back to the surface. The time interval necessary to complete the procedure was measured with a stop watch. All suspended sediment samples were analyzed by the Water Resources Branch of the Department of Energy, Mines and Resources.

Dissolved oxygen, pH, turbidity, alkalinity, hardness, phosphate and sulphate were monitored throughout the study (Table 2). Dissolved oxygen was determined by the standard Winkler method using 0.025 N sodium thiosulphate. Rawson's Nomogram (Reid, 1961) was used to calculate per cent oxygen saturation. A Hellige color disk comparator using Creosol-red-B and Bromthymol-blue-D indicators was employed to measure hydrogen ion concentrations. Turbidity, alkalinity, hardness, phosphate and sulphate were measured with the Hach Model DR-EL water analysis kit. During the summer, all measurements were made in the

TABLE 2. Summary of physical, chemical and biological sampling programme

	1967 May	June	July		Aug	Sept	Oct	Nov	Dec	1968 Feb	Apr	May	June
Physical													
Discharge		1----	----	----	----	----	----31						
Suspended sediment		3----	----	----	----	----15							
Temperature		15----	----	----	----	----	----19						
Turbidity					9	15	14	18	15	23	5	8	11
Chemical													
Hydrogen ion	26	15	6		9	15	14	18	15	23	5	8	11
Dissolved oxygen	26	15	6		9	15	14	18	15	23	5	8	11
Total phosphate					9	15	14	18	15	23	5	8	11
Sulphate					9	15	14	18	15	23	5	8	11
Total alkalinity	26	15	6		9	15	14	18	15	23	5	8	11
Total hardness	26				9	15	14	18	15	23	5	8	11
Biological													
Regular dip		15	6	29	18	12	14	18		23	5	6	6
Fine dip		15	6	29	18	12	14	18	15	23	5	6	6
Regular Surber		15	6	29	18	12	14	18		23	5	6	6
Fine Surber		15	6	29	18	12	14	18	15	23	5	6	6
Adult collections	26----	----	----	----	----	----15					15----	----	----30

--------------- — Indicates continuous monitoring between dates.

field; in the winter, pH, dissolved oxygen and turbidity were measured in the field, and the remainder of the chemical analysis was conducted in the laboratory within 24 hours of the sampling time. During the ice-free period, water temperatures were continuously recorded with a Negretti and Lambra thermograph. Winter water temperatures were taken with a hand thermometer.

Biological

Biological sampling of Wampus Creek started in May 1967 and continued through June 1968. Biological sampling was confined to a riffle section located approximately 1 km upstream from the mouth of Wampus Creek (Fig. 1). The riffle section was about 100 m in length with a mean width of 5 m during peak flow. The substrate consisted of rubble, coarse gravel and fine gravel (Fig. 2). During the summer months, sampling was conducted every 3 weeks; in the winter, attempts were made to visit the creek every other month (Table 2).

For the qualitative samples, two long-handled dip nets with different mesh sizes were used. The nets had mesh sizes of either 40 or 60 meshes per inch (16 or 24 meshes per cm), hereafter referred to as "regular meshed" and "fine meshed" respectively. The sampling technique was similar to that described by Hynes (1961). The net was held on the stream bed and the area immediately upstream was vigorously stirred by foot. After each "kick", the contents of the net were emptied into a white dish; this procedure was continued for 10 minutes. Samples were then transferred to jars and preserved in 10% formalin.

For the quantitative samples, each of two Surber samplers, having the same mesh size as the dip nets, was used to sample 5 ft^2 of substrate; i.e. five "one-foot" square samples were taken at intervals

Fig. 2. Upstream view of riffle section of Wampus Creek used for biological sampling.

across the width of a riffle section. These samples were handled in the same manner as the dip net samples.

During the winter, the thick ice cover of the stream was removed using a chain saw equipped with an ice chain. The area sampled with the dip nets was restricted because of the work required to expose the stream bed. Winter Surber samples were not restricted in terms of area; however, sampling efficiency was reduced because of handling the substrate in the cold water.

Modified samplers were used on 6 June 1968. Both the dip net and the Surber sampler were constructed with double bags; the mesh sizes being 40 and 60 threads per inch (16 and 24 per cm), hereafter referred to as composite dip net and composite Surber sampler. The fine meshed bag was attached with a zipper to the outside of the regular meshed bag (Fig. 3). Samples were taken in the same manner as above, the contents of each bag being treated separately. The basic assumption here is that organisms captured in the regular meshed bag would likewise be captured in the fine meshed one. Similarly, organisms that pass through the regular mesh would not pass through the fine mesh. Thus, the fine mesh bag should provide both a qualitative (species present) and quantitative (numbers or biomass) assessment of organisms that passed through the regular meshed bag.

Adult insects were collected by "sweeping" the grass and trees with a long-handled butterfly net. Some adult specimens were also obtained at night using a lantern. Adults were stored in 95% ethyl alcohol for subsequent identification.

All samples were returned to the laboratory for sorting. A saturated sucrose solution was used to "float" the organisms, which were

Fig. 3. A. Composite dip net

B. Composite Surber sampler

Symbols: C Coarse mesh netting

F Fine mesh netting

Z Zipper

A

B

then stored in 95% ethyl alcohol. Each type of sample—regular meshed dip, fine meshed dip, regular meshed Surber and fine meshed Surber—was analyzed separately.

General taxonomic keys used to identify the aquatic insects were Pennak (1953), Usinger (1963), and Ward and Whipple (1959). For Ephemeroptera, specific keys were Needham, Traver and Hsu (1935), Edmunds (1959), Allen and Edmunds (1959, 1961*a*, 1961*b*, 1961*c*, 1962, and 1965), and Edmunds and Allen (1964); for Plecoptera, specific keys were Ricker (1943) and Jewett (1959). However, it was impossible to identify most of the mayfly and stonefly nymphs to species. Dipterans and larval trichopterans were identified only to family.

Total length measurements to the nearest 0.5 mm, excluding the cerci, were made for the more abundant species of mayflies and stoneflies. When the number of individuals of a species in a sample was high (above 150), instead of measuring each specimen, a random sub-sample was taken. This was done by placing all the specimens in a petri-dish containing 70% ethyl alcohol. The dish was gently rotated until the specimens were judged to be evenly distributed. A plastic grid was placed into the dish effectively dividing the sample into four parts. If the number of organisms in the sub-division was still too large, the procedure was repeated with one of the sub-samples. Biomass was determined volumetrically following the procedure of Welch (1948).

PHYSICAL AND CHEMICAL CHARACTERISTICS OF WAMPUS CREEK

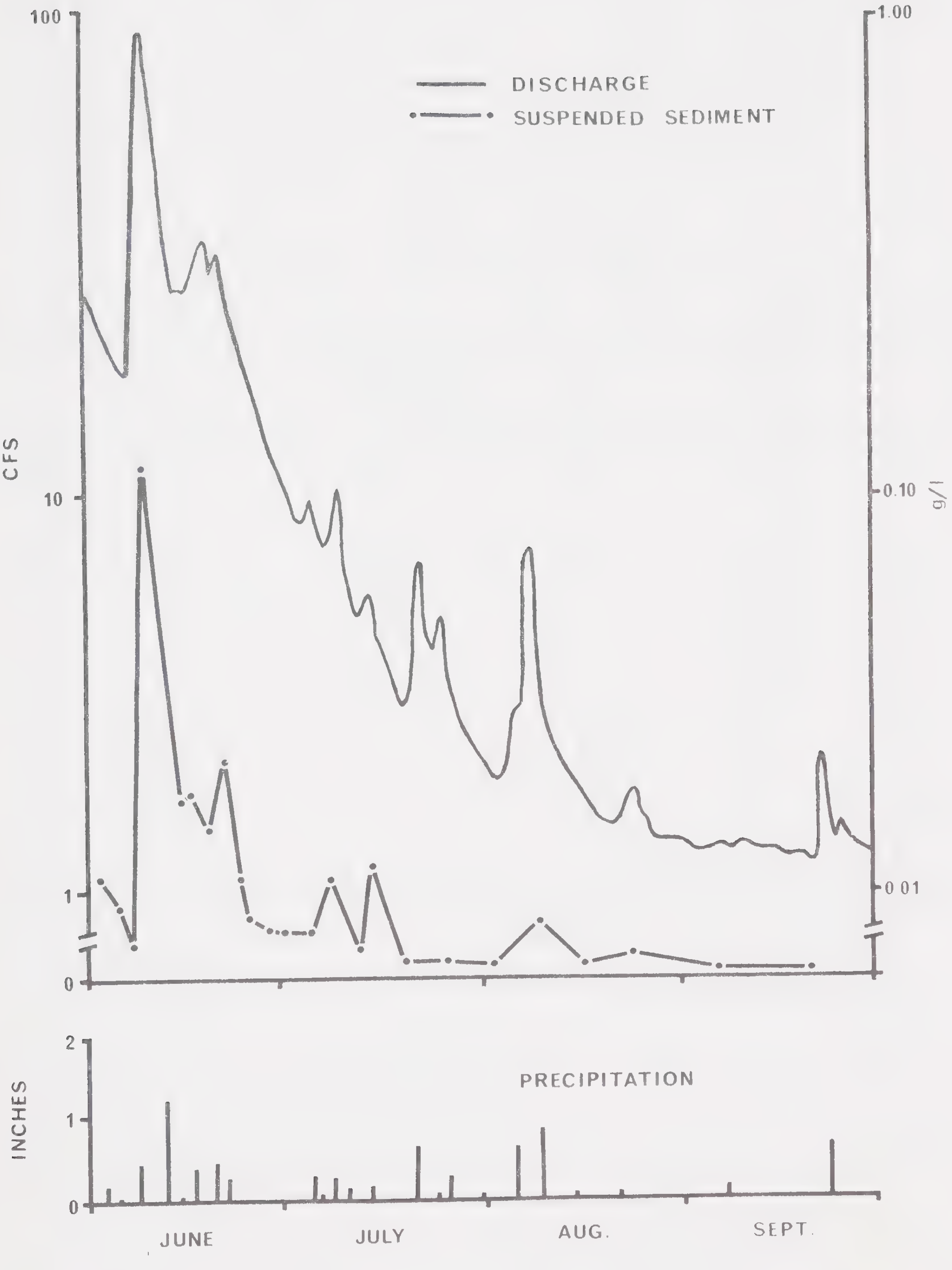
Stream discharge

Wampus Creek reached maximum discharge during the ice break-up in the spring, when the snow was melting. On 26 May 1967 a maximum discharge of 145 cfs was recorded. Discharge decreased during the summer months, reaching a mean monthly low of 1.8 cfs in September (Fig. 4). Fluctuations in the pattern of discharge during the summer paralleled the periods of precipitation. The lack of precipitation in the Wampus Creek basin during the ice free season resulted in unusually low discharge in the autumn of 1967. In October 1966 the mean discharge was 5.9 cfs with a minimum of 3.7 cfs, while in September 1967 the stream had already reached a mean of 1.8 cfs with a minimum of 1.5 cfs (Table 3). Although stream discharge was not monitored in winter, personal observations indicated that flow during the 1967-1968 winter was lower than for the same period of 1966-1967.

Suspended sediment

The maximum sediment value was 0.127 g/l obtained in June 1967 (Fig. 4). This peak corresponded to a peak in the spring discharge. At this time the stream became turbid due to the run-off associated with the spring melt. With decreasing discharge, suspended sediment also decreased; fluctuations in the concentrations of suspended sediment paralleled those of discharge. Undoubtedly, a portion of the suspended sediment in Wampus Creek is autochthonous (i.e. the result of natural scouring of the stream channel); however, roads and seismic lines in the study area could have contributed some allochthonous suspended sediment.

Fig. 4. Discharge and suspended sediment of Wampus Creek, and precipitation in the watershed, 1 June to 30 September 1967.



100
10
1
0
CFS
1.00
0.10
0.01
g/l
DISCHARGE
SUSPENDED SEDIMENT
2
1
0
INCHES
PRECIPITATION
JUNE
JULY
AUG.
SEPT.

TABLE 3. Discharge of Wampus Creek

Year	Month	Total Discharge (cfs)	Mean	Maximum	Minimum
1966	Oct.	182.6	5.9	10.9	3.7
1967	June	892.2	29.9	93.0	11.2
	July	189.7	6.1	10.5	2.9
	Aug.	88.8	2.9	7.8	1.9
	Sept.	53.4	1.8	2.9	1.5
	Oct.	57.6	1.9	2.2	1.7
	Nov.	37.4	1.2	2.1	0.49

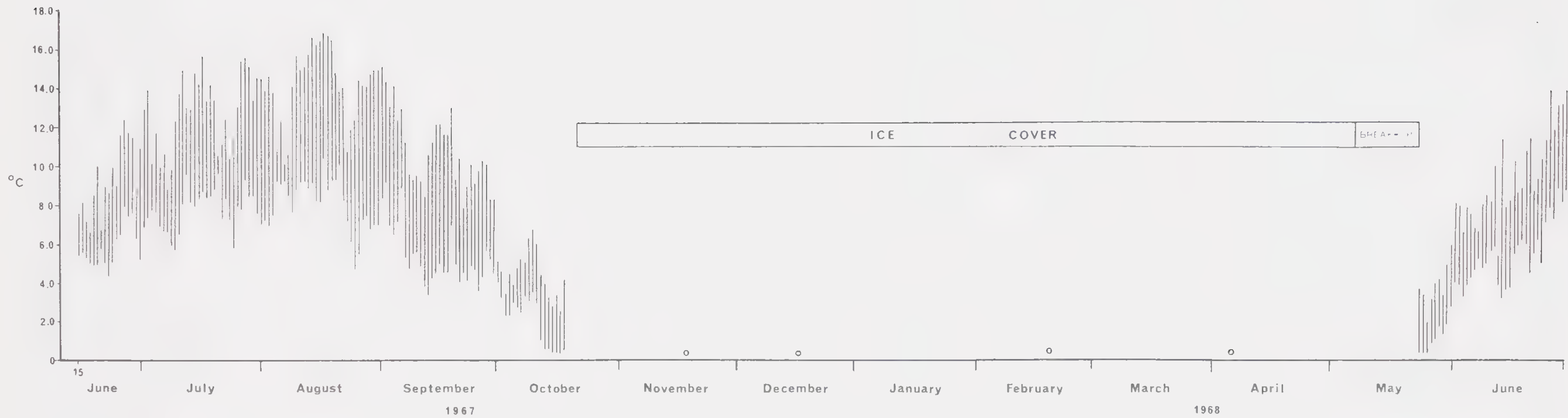
Temperature and ice conditions

Monitoring of water temperature began on 15 June 1967; water temperatures rose in June and then levelled off during July (Fig. 5). During July and August, wide daily water temperature fluctuations occurred, reflecting at this time wide daily fluctuations in air temperatures. By late August and early September, decreasing daily air temperatures resulted in decreasing water temperature, with very little daily fluctuations. Surface ice was first noted on 19 October 1967, and it persisted until the spring break-up, which began during the first week of May 1968. The spring break-up continued for about 3 weeks. With the disappearance of the ice, water temperatures started to fluctuate slightly, thus resuming the previous June pattern.

The ice cover during the winter of 1967-1968 was atypical and is probably accounted for by the lack of precipitation in the summer and autumn of 1967. The low discharge in autumn of 1967 resulted in ice forming close to the substrate. As the winter progressed and air temperatures fell to as low as -38 C°, the surface ice made contact with extensive portions of the substrate. On 23 February 1968, a 30 cm strip of ice, extending across the entire width of a riffle section, was removed from the stream; surface ice extended into the substrate across the entire stream bottom, and there was no flow in the riffle section, but flow was found downstream. In the riffle section, flow must have occurred deep in the substrate. At this time, channel changes were observed in other sections. One could locate, by chiseling through the surface ice, the dry channel through which water had previously flowed. Undoubtedly, an ice dam formed upstream that caused the channel to relocate. Maciolek and Needham (1952) observed

Fig. 5. Daily range of water temperatures of Wampus Creek, 15 June 1967 to 30 June 1968. Automatic recorder was removed 19 October 1967 and replaced 23 May 1968.

△ represents measurements taken with hand thermometer.



°C
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0
15
ICE COVER
June
July
August
September
October
November
December
January
February
March
April
May
June
1967
1968

similar ice conditions in Convict Creek and noted mortality of aquatic invertebrates at this time.

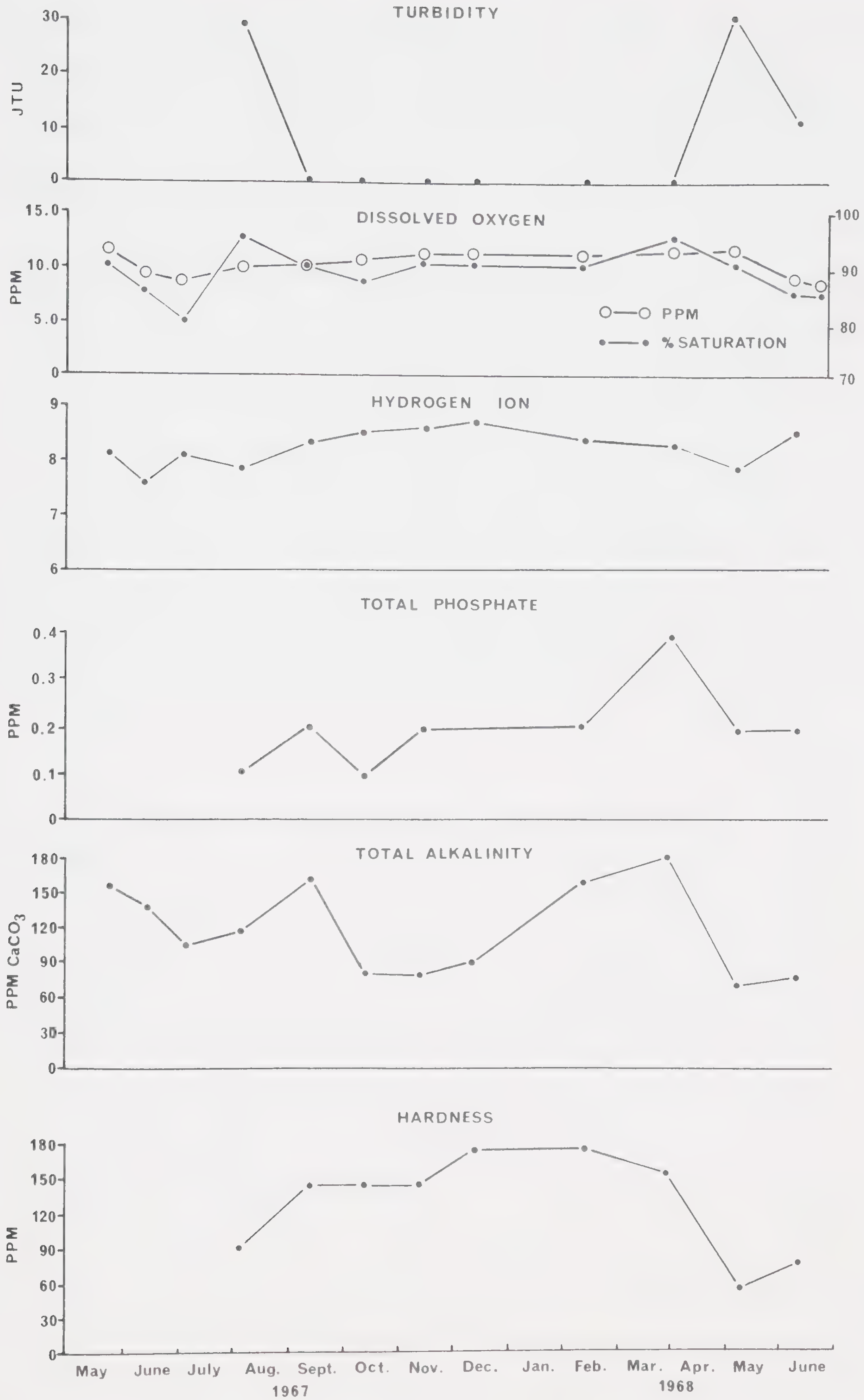
Melting due to unusually warm weather in February 1968 contributed further to the unusual ice conditions. A flow of melt water over the existing ice and then freezing temperatures at night caused "overflow" ice to form; in some sections of the stream the total ice thickness was 1 m.

Macan (1958*a*), studying the yearly temperatures of a moorland stream in the Lake District of Britain, recorded mean weekly temperatures above 10° C for 24 weeks and mean weekly water temperatures below 5° C for only 12 weeks. In Wampus Creek, mean weekly temperatures above 10° C were recorded for 7 weeks, while temperatures below 5° C were recorded for 36 weeks. The temperature regime of Wampus Creek was similar to that recorded by Hartland-Rowe (1964) for a small trout stream, Gorge Creek, located approximately 330 km southeast of Wampus Creek. Gorge Creek had temperatures above 10° C for 7 weeks and below 5° C for 39 weeks. Macan found that his stream accumulated 30,500 degree hours for the 30 weeks following the beginning of October. The comparable figure for Wampus Creek was 1,440 degree hours, which was similar to the 1,221 degree hours recorded by Hartland-Rowe (1964) for Gorge Creek. The total for the year in Gorge Creek was less than 30,000 degree hours; for Wampus Creek the total was 28,650.

<u>Turbidity</u>

Although turbidity readings were not taken at regular intervals, the values that were obtained showed a direct relationship with flow (Fig. 6). Spring and summer readings were below 30 Jackson Turbidity Units, while readings of 0 JTU were obtained during the autumn and winter.

Fig. 6. Physical and chemical characteristics of Wampus Creek, May 1967 to June 1968.


TURBIDITY
JTU
0
10
20
30
DISSOLVED OXYGEN
PPM
0
5.0
10.0
15.0
%
70
80
90
100
PPM
% SATURATION
HYDROGEN ION
6
7
8
9
TOTAL PHOSPHATE
PPM
0
0.1
0.2
0.3
0.4
TOTAL ALKALINITY
PPM $CaCO_3$
0
30
60
90
120
150
180
HARDNESS
PPM
0
30
60
90
120
150
180
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
1967
1968

The turbidity readings of Wampus Creek are generally lower than the 35-90 JTU reported for Wandering River (Robertson, 1967) and 14-42 JTU reported for the Bigoray River (Clifford, 1969), both muskeg rivers of Alberta.

Chemical characteristics

For the entire study period, the pH of Wampus Creek varied only from 7.5 to 8.6 (Fig. 6). Dissolved oxygen levels were relatively high at all times (Fig. 6). The percentage saturation was never observed below 80%, while the lowest concentration was 8.3 ppm on 27 June 1968. Total phosphate concentrations, varying from 0.1 to 0.4 ppm, were much lower than those obtained by Robertson (1967) for the La Biche River and the Wandering River of northeastern Alberta; and they were slightly lower than those obtained by Clifford (1969) for the Bigoray River. Total alkalinity varied from 70 to 180 ppm $CaCO_3$; hardness varied from 50 to 170 ppm.

SPECIES COLLECTED

During the study period, 14 species of mayflies, 25 species of stoneflies, 14 species of caddisflies, and representatives of six families of dipterans were collected (Table 4); several specimens of other taxa were also obtained. Although 14 species of mayflies were collected, positive nymph-adult associations were possible for only six of these. The mayfly fauna was composed entirely of Cordilleran species.

Positive nymph-adult associations were possible for only seven of the 25 stonefly species. The remaining species will require more taxonomic investigations. The entire stonefly fauna of Wampus Creek is that of Cordilleran species. Ricker (1964) listed *Isoperla ebria*, *Kathroperla perdita*, *Alloperla severa*, and *Nemoura cinctipes* as postglacial invaders from the southern Cordillera. *Capnia (Utacapnia) trava* represents a range extension; this is the first report of this species from Canada (Nebeker, personal communication).

Fourteen species of trichopterans were collected, five of these being *Rhyacophila* species. Although larvae of *Rhyacophila* spp. were abundant, positive larval-adult associations were not possible. The remaining species occurred in small numbers.

TABLE 4. Species list of aquatic invertebrates from Wampus Creek, and the total number for each species (or higher taxon) collected by all samplers during the study period 15 June 1967 to 6 June 1968. The asterisk indicates species identified to given level by adult stages; identification not possible for immatures

	Total Number
Ephemeroptera	
Ameletus spp.	2,255
**Ameletus oregonensis* Eaton	
**Siphlonurus columbianus* Eaton	
Cinygmula spp.	19,372
**Cinygmula kootenai* McDunnough	
**Cinygmula ramaleyi* (Dodds)	
**Cinygmula reticulata* McDunnough	
Epeorus longimanus (Eaton)	1,900
Epeorus (Ironopsis) sp.	18
Rithrogena spp.	458
Baetis sp.	17,398
Paraleptophlebia sp.	211
Ephemerella coloradensis Dodds	189
Ephemerella doddsi Needham	1,802
Ephemerella inermis Eaton	315
Ephemerella grandis ingens McDunnough	152
Ephemerella tibialis McDunnough	59
Plecoptera	
Nemoura decepta Frison	726
**Nemoura delicatula* Claassen	
Nemoura cinctipes Banks	1,824
**Nemoura columbiana* Claassen	
Nemoura oregonensis Claassen	766
Paraleuctra sp.	180
**Paraleuctra occidentalis* Banks	
**Capnia coloradensis* Claassen	
**Capnia columbiana* Claassen	
**Capnia trava* Nebeker & Gaufin	

Plecoptera (continued)

Capnia sp.	307
**Eucapnopsis brevicauda* (Claassen)	
Brachyptera nigripennis (Banks)	3,087
Arcynopteryx (Megarcys) sp.	18
Arcynopteryx curvata Hanson	278
Isogenus nonus (Needham & Claassen)	734
Isoperla spp.	136
**Isoperla ebria* (Hagen)	
**Isoperla fusca* Needham & Claassen	
**Kathroperla perdita* Banks	
Alloperla spp.	1,674
**Alloperla fidelis* Banks	
**Alloperla coloradensis* (Banks)	
**Alloperla borealis* (Banks)	
**Alloperla albertensis* Needham & Claassen	
**Alloperla* sp. (? serera)	
**Alloperla pallidula* (Banks)	
**Alloperla signata* Banks	
Acroneuria pacifica Banks	808

Trichoptera

Family Rhyacophilidae	1,559
**Rhyacophila valuma* Milne	
**Rhyacophila vofixa* Milne	
**Rhyacophila acropedes* Banks	
**Rhyacophila angelita* Banks	
**Rhyacophila verrula* Milne	
**Glossosoma* sp.	
Family Hydropsychidae	17
Family Limnephilidae	91
**Chyranda centraus* Banks	
**Limnephilus* sp.	
**Dicosmoecus* sp.	
**Oligophlebodes* n. sp.	

Trichoptera (continued)	
*Family Phryganeidae	
Apatania sp.	
*Family Lepidostomatidae	
Lepidostoma sp.	
Family Brachycentridae	185
**Brachycentrus* sp.	
**Micrasema* sp.	
Diptera	
Tipulidae	248
Simuliidae	428
Ceratopogonidae	120
Family Chironomidae	
Chironominae	471
Orthocladinae	3,272
Family Psychodidae	356
Megaloptera	
**Sialis* sp.	
Coleoptera	
Heterlimnius sp.	3,018
Collembola	6
Hydracarina	102
*Nematomorpha	8
Tricladida	15

LIFE HISTORIES

Ephemeroptera

Ephemerella doddsi Needham, *Ephemerella grandis ingens* McDunnough, *Ephemerella inermis* Eaton

The life cycles of these three species were similar (Fig. 7). Emergence occurred during July and small nymphs of the new generation appeared by late July. The nymphs grew rapidly during summer and early autumn; but with the approach of winter, growth slowed down or stopped. Growth resumed in April and continued until emergence. The life cycle of *E. inermis* was similar to that found by Hartland-Rowe (1964) for the same species in Gorge Creek, a mountainous stream of southern Alberta. The life histories of the above species can be classified as univoltine, with a short summer emergence period, immediate hatching, and growth primarily in summer, early autumn and spring.

Ephemerella coloradensis Dodds

E. coloradensis had a slightly different life cycle from the above three *Ephemerella* species (Fig. 8). Adults emerged and oviposited during July and August; but small nymphs were not found until November, hatching apparently being delayed in this species. Only small nymphs (1.0 to 2.0 mm) were collected during the winter, growth not accelerating until April. The life cycle of the univoltine *E. coloradensis* was characterized by summer emergence, delayed hatching, no winter growth, and accelerated spring growth.

Ephemerella tibialis McDunnough

E. tibialis was only collected on 29 July and 18 August 1967; unfortunately a sample was not taken in July 1968 for verification of

Fig. 7. Length-frequency histograms of *Ephemerella doddsi*, *Ephemerella inermis* and *Ephemerella grandis ingens*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence. Data for life histories of *E. inermis* and *E. grandis ingens* represents combined collections of fine and regular meshed dip nets.

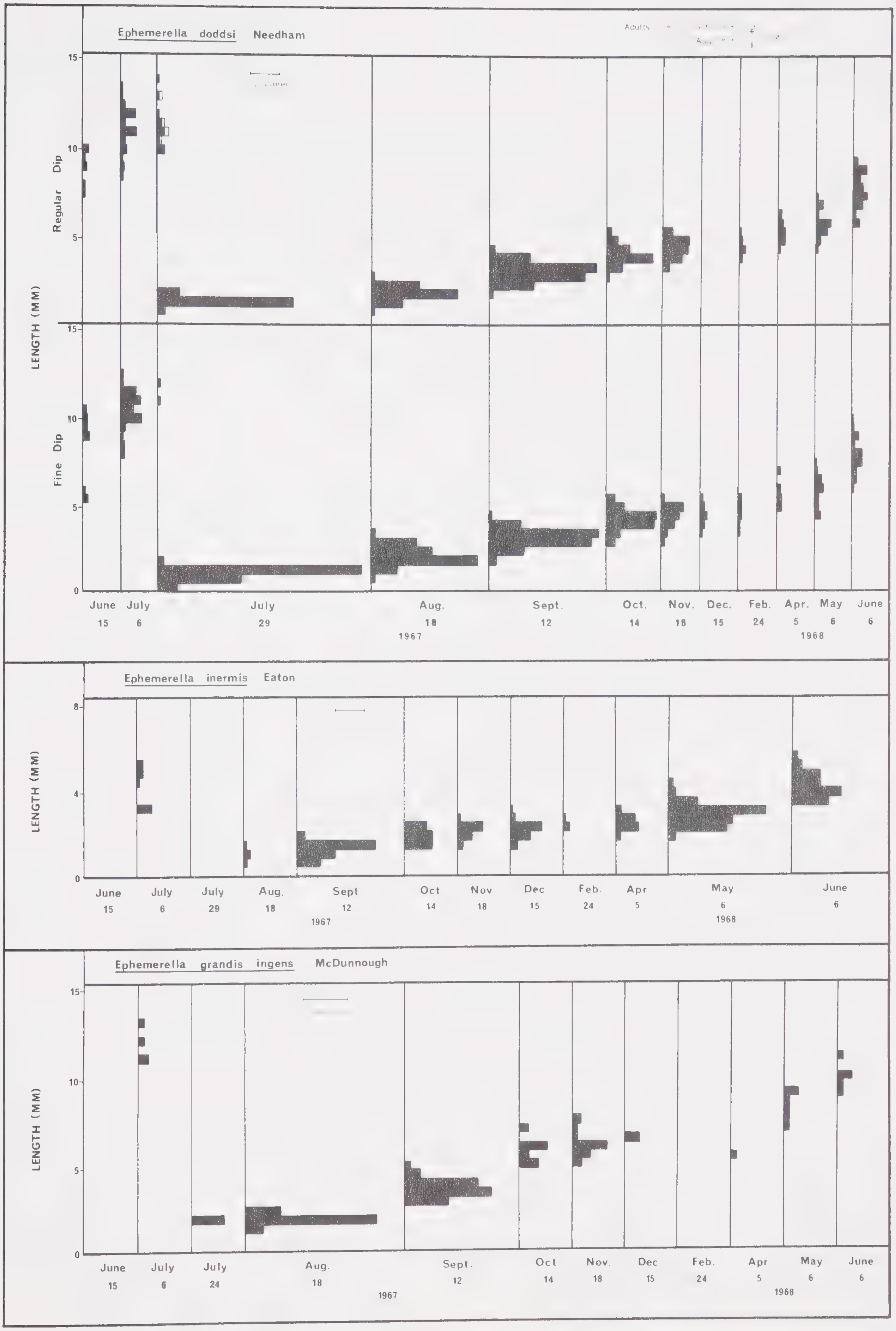
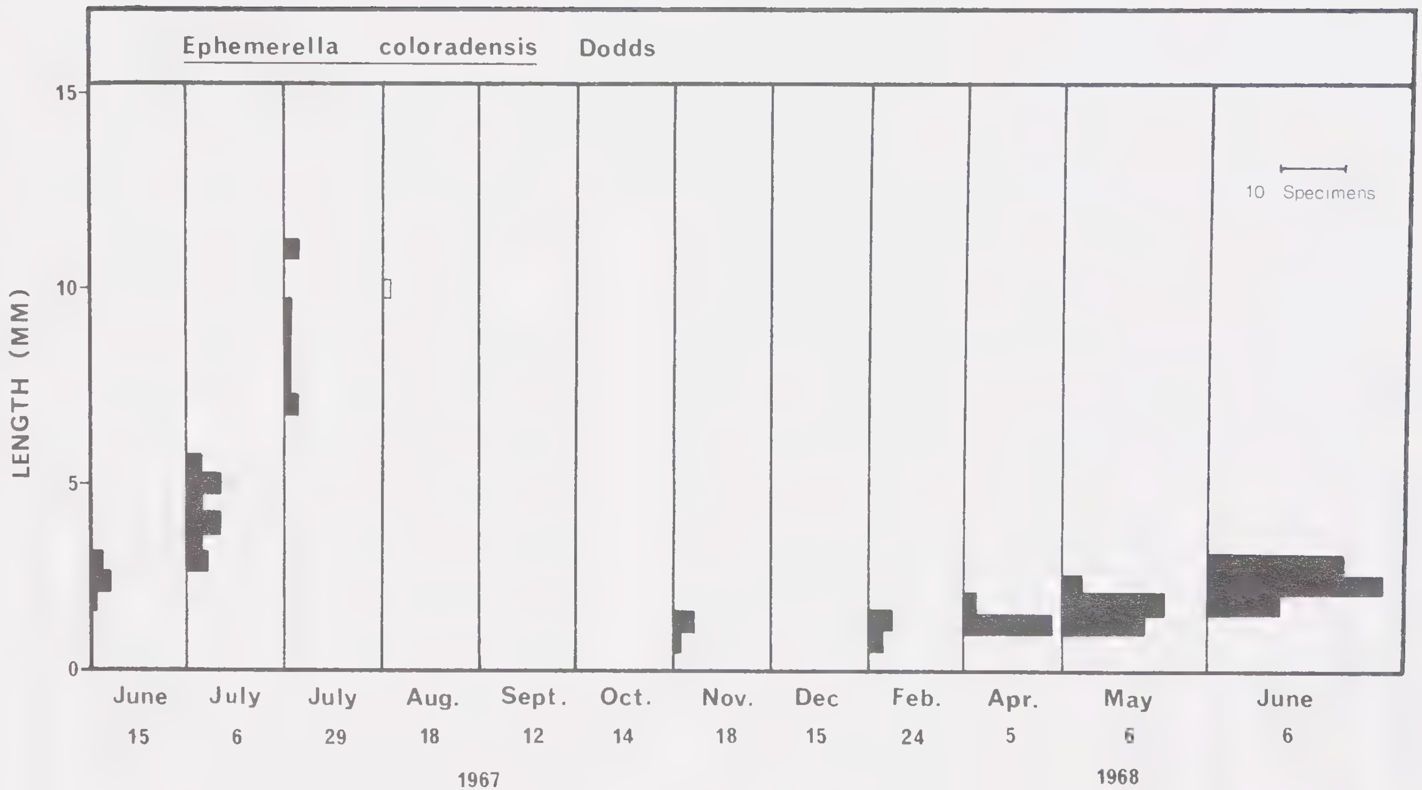

Ephemerella doddsi Needham
LENGTH (MM)
Regular Dip
Fine Dip
0
5
10
15
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
1967
Feb. 24
Apr. 5
May 6
June 6
1968
Ephemerella inermis Eaton
LENGTH (MM)
0
4
8
June 15
July 6
July 29
Aug. 18
Sept 12
Oct 14
Nov 18
Dec 15
1967
Feb. 24
Apr 5
May 6
June 6
1968
Ephemerella grandis ingens McDunnough
LENGTH (MM)
0
5
10
15
June 15
July 6
July 24
Aug. 18
Sept. 12
Oct 14
Nov. 18
Dec 15
1967
Feb. 24
Apr 5
May 6
June 6
1968

Fig. 8. Length-frequency histogram of *Ephemerella coloradensis*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence. Collections with fine and regular meshed dip nets combined.


Ephemerella coloradensis Dodds
LENGTH (MM)
15
10
5
0
10 Specimens
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

the 1967 collections (Fig. 9). *E. tibialis* probably is a summer, or temporary, mayfly species. Mature nymphs, indicated by darkened wing pads, were collected on 18 August 1967. Although no subimagos or adults were captured, emergence and oviposition undoubtedly took place in the latter part of August and early September. Assuming nymphs reappeared in July 1968, this would suggest a long period during which the eggs were dormant. After hatching, the nymphs would grow rapidly, and the complete growth and emergence phase of the life cycle would be completed in 6 to 8 weeks. Summer or temporary species have also been reported for *Ameletus ludens* Clemens (1922); *Parameletus columbiae* McD., Edmunds (1957); *Ephemerella ignita* (Poda), Macan (1957*b*); *Heptagenia* prob. *maculipennis* Walsh, Clifford (1966*a*); *Tricorythodes minutus* Needham, Robertson (1967) and *Cloeon* sp., *Siphlonurus alternatus* (Say) and *Paraleptophlebia debilis* (Walker), Clifford (1969).

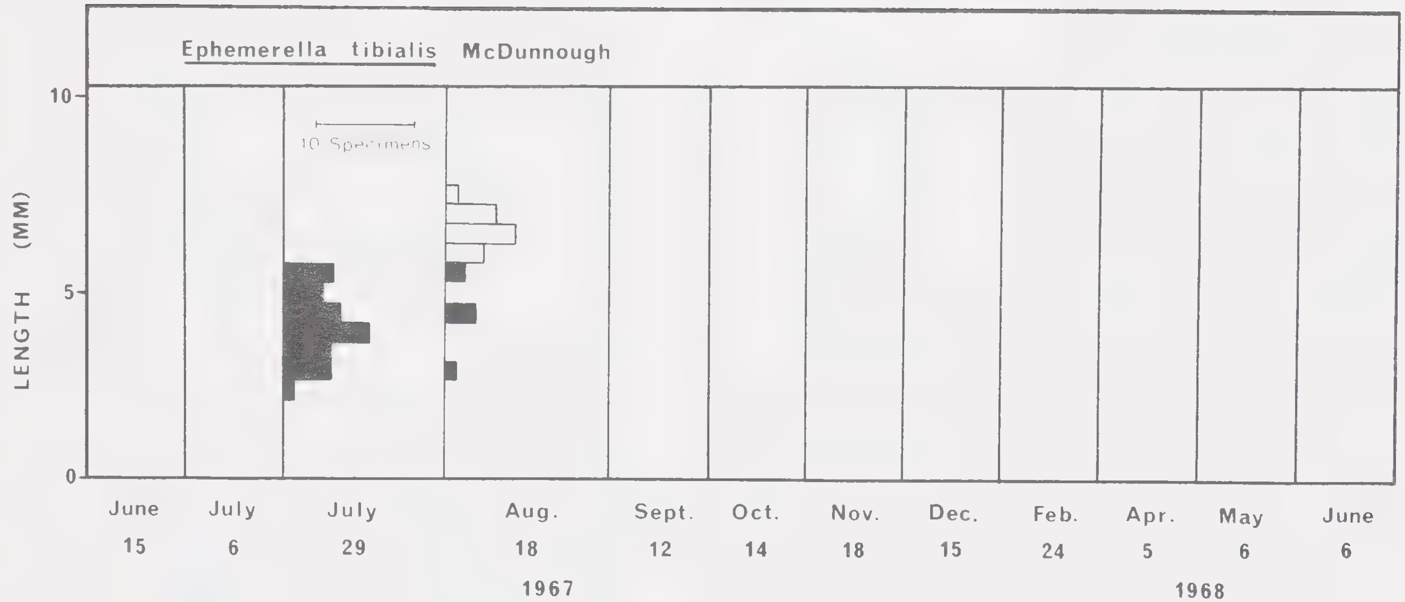
Epeorus longimanus (Eaton)

E. longimanus had a univoltine cycle with emergence extending from July through October (Fig. 10). Hatching was somewhat delayed; small nymphs grew very little during the winter, but growth accelerated in the spring, and the nymphs continued to grow throughout the summer. Hartland-Rowe (1964) described the life history of *E. longimanus* in Gorge Creek. In his study, small nymphs did not appear until April, but he was not using a fine meshed net. Lehmkuhl (1968) studied the life history of *E. longimanus* in a western Oregon stream. He reported emergence from April to June, but the new generation did not appear until September, suggesting that the eggs remained dormant for several months.

Rhithrogena sp.

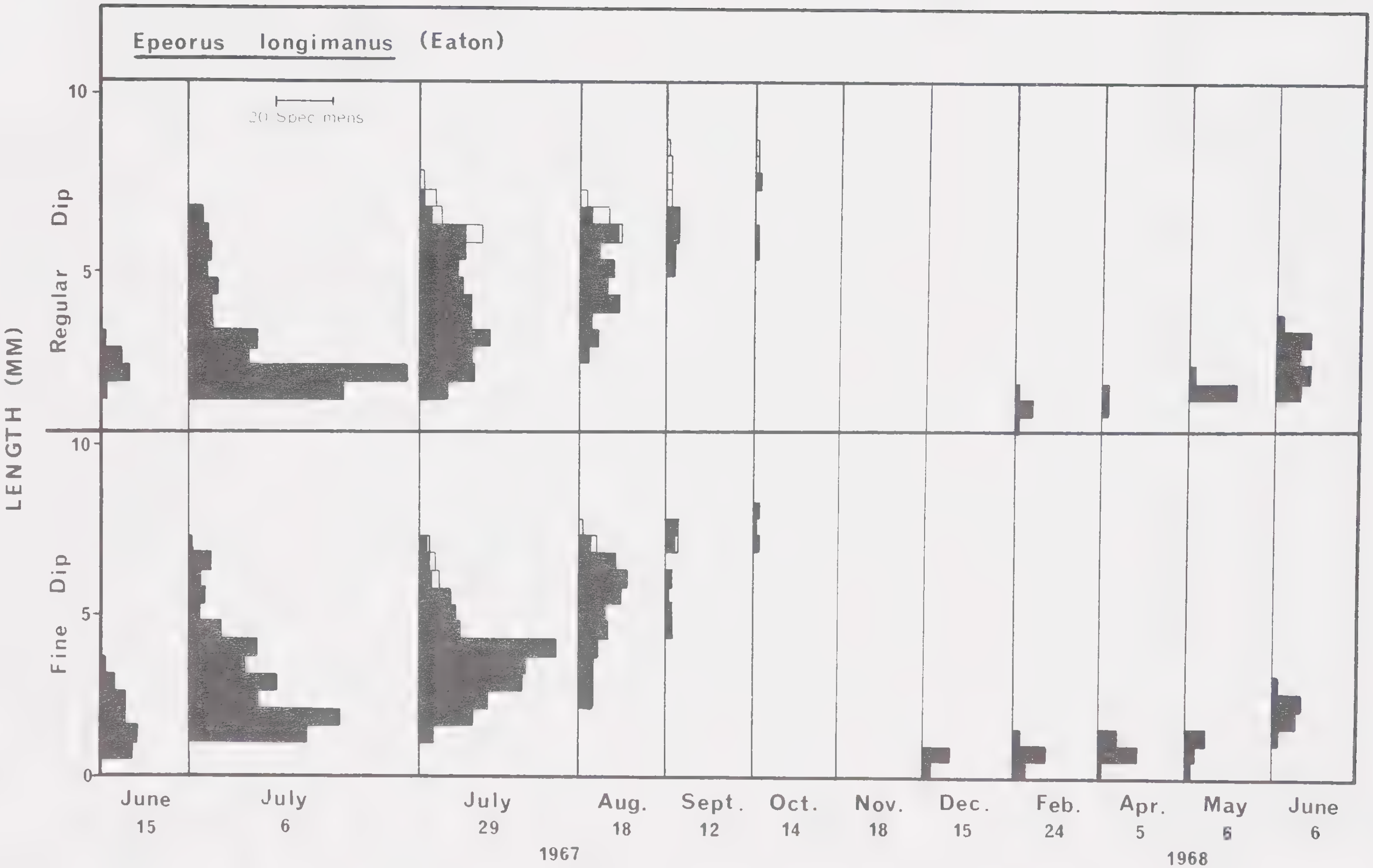
It was difficult for Hartland-Rowe (1964) to distinguish nymphs

Fig. 9. Length-frequency histogram of *Ephemerella tibialis*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence. Collections with fine and regular meshed dip nets combined.



Ephemerella tibialis McDunnough
10 Specimens
LENGTH (MM)
10
5
0
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

Fig. 10. Length-frequency of *Epeorus longimanus*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence.



Epeorus longimanus (Eaton)
20 Specimens
LENGTH (MM)
Regular Dip
Fine Dip
10
5
0
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

of *Rhithrogena virilis* from *R. robusta* and *R. doddsi;* I found a similar situation for *Rhithrogena* in Wampus Creek. *Rhithrogena virilis* was present, but the bimodal appearance of the size-frequency histogram suggested the presence of another species (Fig. 11). The data suggest that *Rhithrogena* had a univoltine cycle with emergence in July and August, subsequent hatching and growth during the summer and autumn, and cessation of growth in the winter. In the spring, growth resumed and development was completed.

Baetis sp.

Baetis sp. possibly has a life cycle consisting of two generations a year, a slow-growing winter generation and a rapid-growing summer generation (Fig. 12). The winter generation appeared in October. Individuals grew little during the winter months, but growth accelerated in May. Emergence of the winter generation occurred in June, July, and August. Offspring of the winter generation, i.e. the summer generation, appeared in July. The individuals grew rapidly during July and August, with emergence occurring in September and October. A noticeable difference occurred between the June 1967 and June 1968 samples. The 15 June 1967 sample contained few individuals in the 1-2 mm size classes whereas the 6 June 1968 sample contained many specimens in the 1-2 mm size classes. The specimens in the 1968 sample may have been the result of delayed hatching of the summer generation eggs, which would have been oviposited the previous autumn; or it possibly resulted from early hatching of eggs oviposited by adults of the winter generation that had emerged in early June. Macan (1957*b*) observed a similar bivoltine cycle for *B. rhodani*. Robertson (1967) reported a similar history of a *Baetis* sp. in a more northerly

Fig. 11. Length-frequency histogram of *Rhithrogena* sp. (or spp.). Collections with fine and regular meshed dip nets combined.

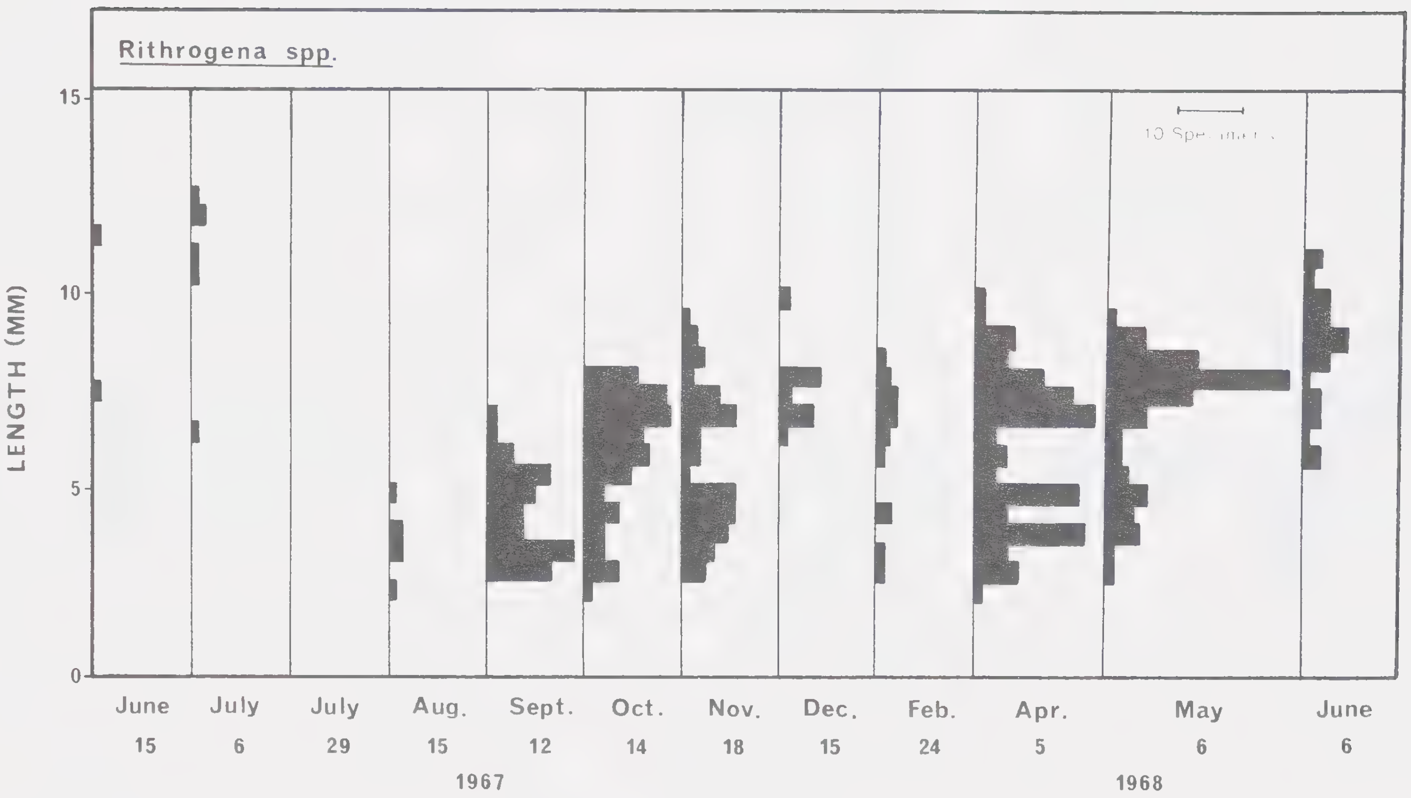
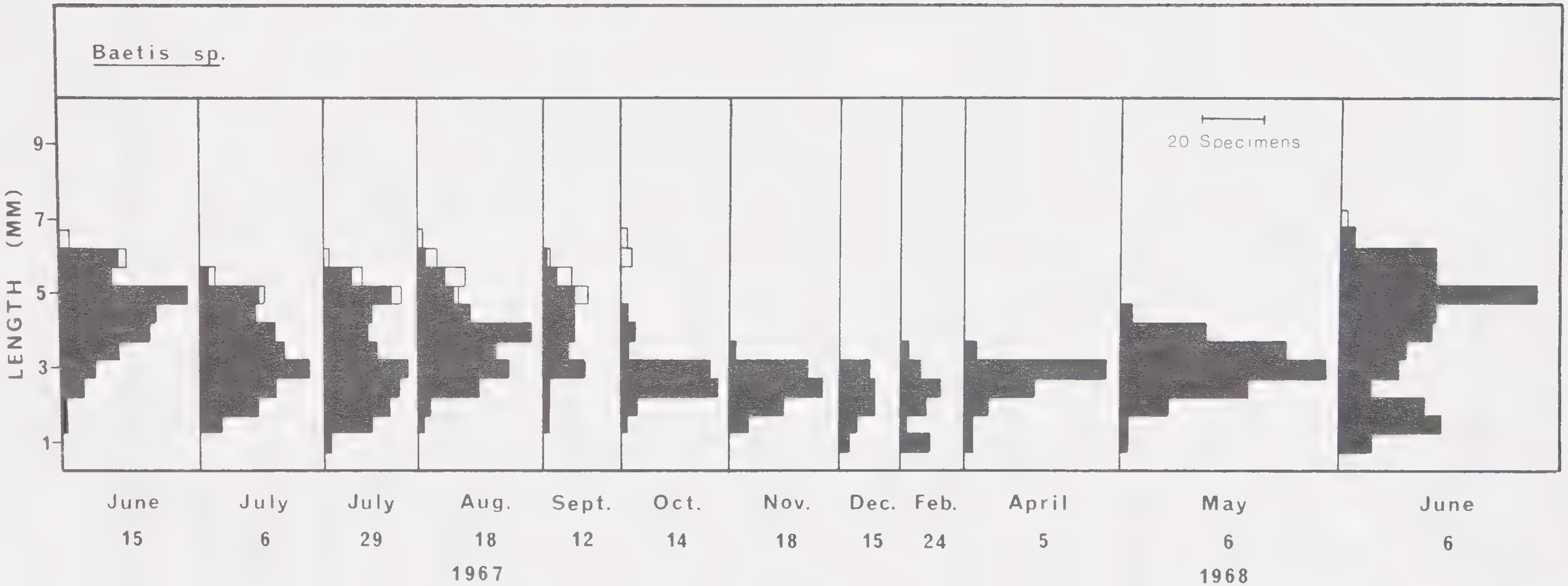

Rithrogena spp.
10 Specimens
LENGTH (MM)
15
10
5
0
June 15
July 6
July 29
Aug. 15
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

Fig. 12. Length-frequency histogram of *Baetis* sp. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence. Specimens collected with fine meshed dip net.


Baetis sp.
LENGTH (MM)
9
7
5
3
1
20 Specimens
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
April 5
May 6
June 6
1967
1968

stream in Alberta. Clifford (1969) examined the life history of *B. tricaudatus* in the Bigoray River of Alberta. He observed an emergence peak in June and another peak in September but a large influx of small specimens did not occur during the summer.

Plecoptera

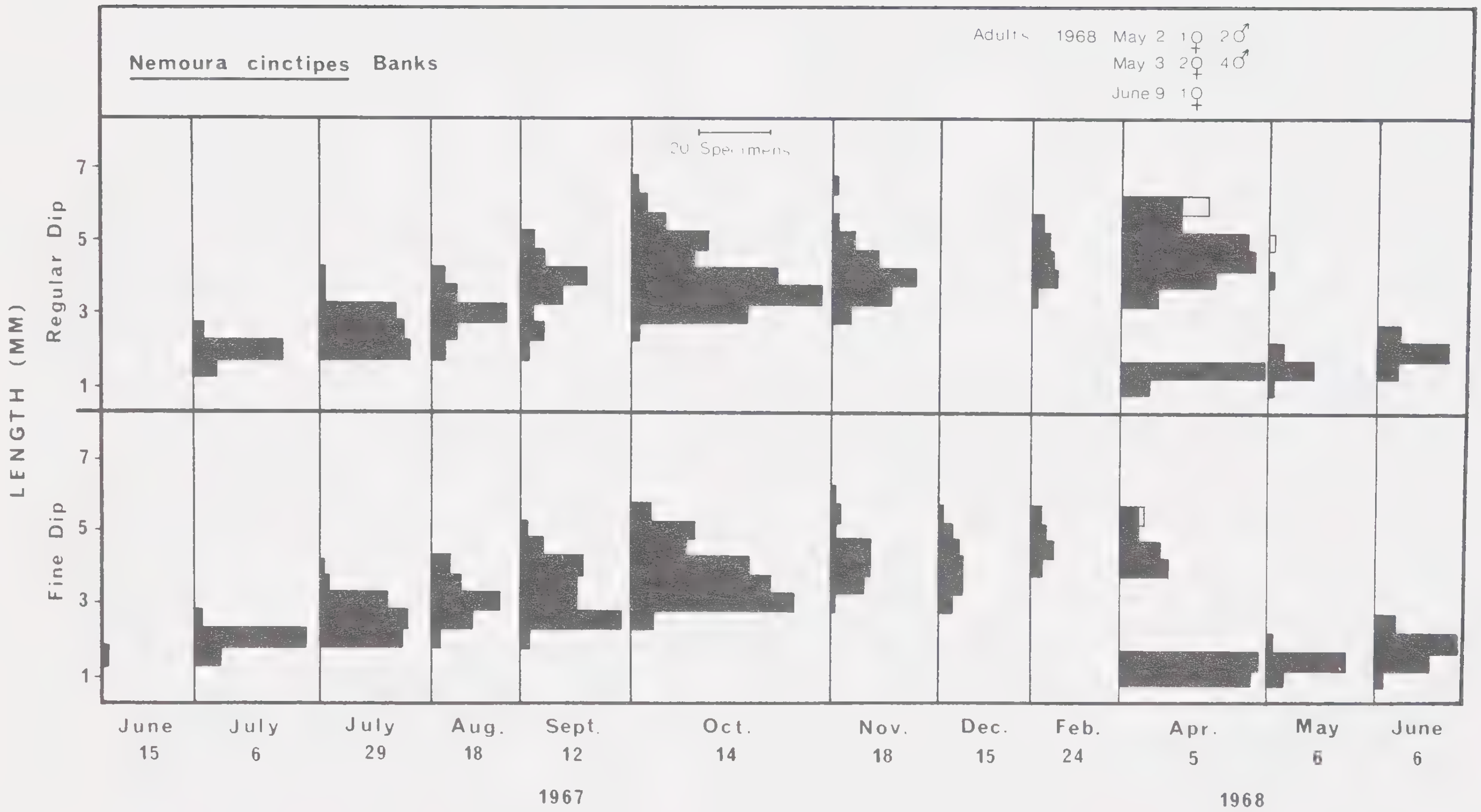
Nemoura cinctipes Banks

N. cinctipes was the first aquatic insect to emerge in the spring (Fig. 13). As soon as openings appeared through the ice, mature nymphs crawled out and dispersed rapidly over the snow. When these nymphs were placed in a glass container partially filled with snow, they emerged within 1 hour. The presence of small nymphs in the 5 April sample is difficult to explain. No adult *N. cinctipes* were found under the ice, although Clifford (1969) collected adults under the ice of the Bigoray River, located approximately 130 km east northeast of Wampus Creek. Sailer (1950) found *N. columbiana* Claassen adults under the ice in an Alaskan stream, and this species not only transformed into the adult stage under the ice, but mated and probably oviposited beneath the ice. A similar phenomenon in Wampus Creek might account for the small nymphs, but hatching would have to be very rapid. It is possible that the small nymphs were in fact a different species, closely resembling *N. cinctipes*. Regardless, the nymphs of the new generation grew rapidly during spring, summer and early autumn. By November, the nymphs appeared fully grown, and there was little growth during the winter months.

Nemoura oregonensis (Claassen)

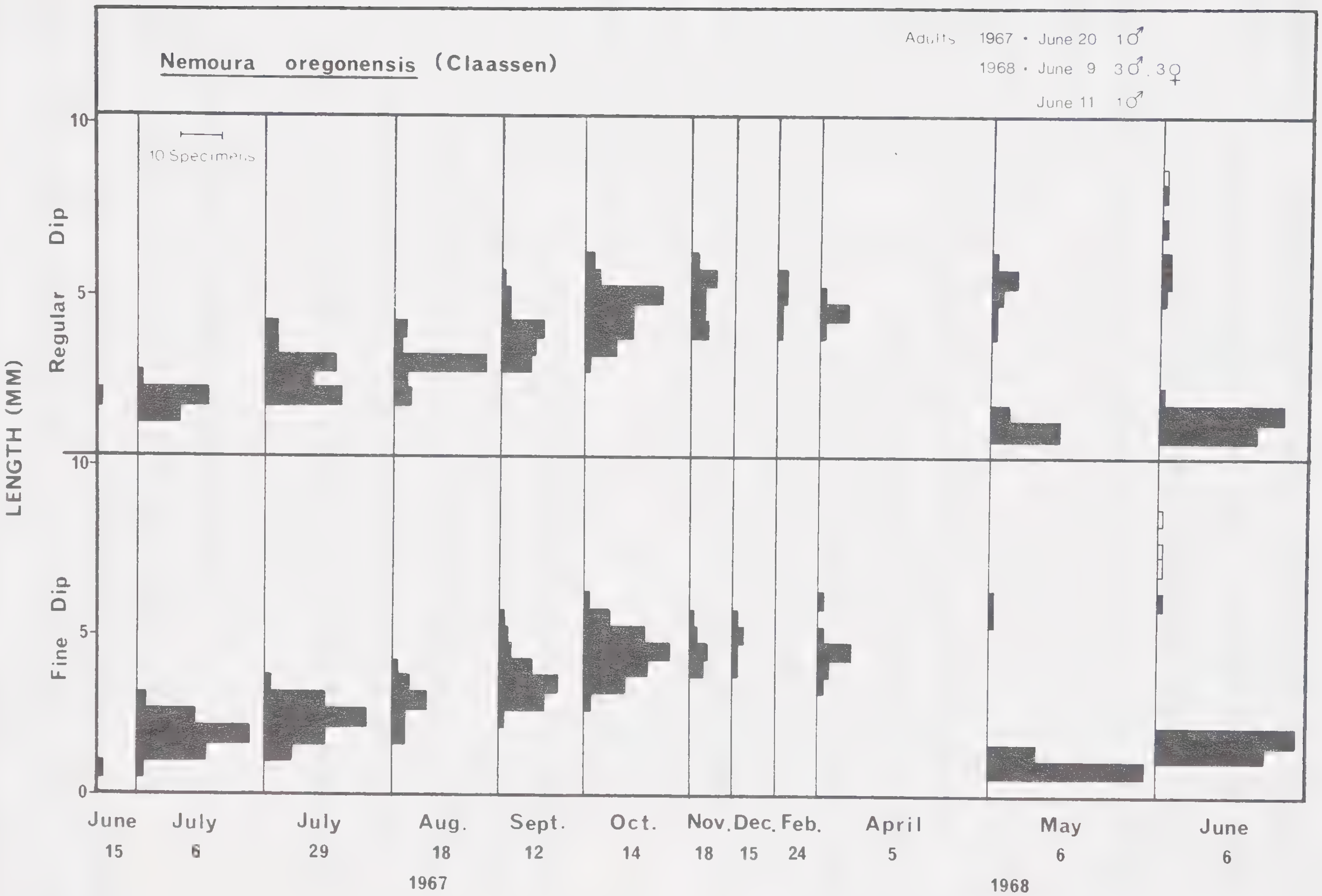
The life cycle of *N. oregonensis* (Fig. 14) was similar to

Fig. 13. Length-frequency histogram of *Nemoura cinctipes*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence.



Nemoura cinctipes Banks
Adults 1968 May 2 1♀ 2♂
May 3 2♀ 4♂
June 9 1♀
20 Specimens
LENGTH (MM)
Regular Dip
Fine Dip
7
5
3
1
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

Fig. 14. Length-frequency histogram of *Nemoura oregonensis*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence.


Nemoura oregonensis (Claassen)
Adults 1967 · June 20 1♂
1968 · June 9 3♂, 3♀
June 11 1♂
10 Specimens
LENGTH (MM)
Regular Dip
Fine Dip
10
5
0
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
April 5
May 6
June 6
1967
1968

N. cinctipes; however, mature nymphs of *N. oregonensis* were collected in the stream on 6 June, a time when the mature nymphs of *N. cinctipes* had disappeared. The small *N. oregonensis* nymphs in the May sample may have been the offspring of the old generation, which emerged in early spring. The nymphs grew during the summer and autumn, but growth ceased during the winter. Growth resumed in the spring and the nymphs transformed in June.

Nemoura decepta Frison

The life cycle of *N. decepta* was different from the above two *Nemoura* species (Fig. 15). Mature nymphs and also adults were collected during June and early July, but the new generation did not appear until February of the following year. The eggs must have remained dormant for about 7 months before hatching. During the spring the nymphs grew rapidly and emergence took place in June.

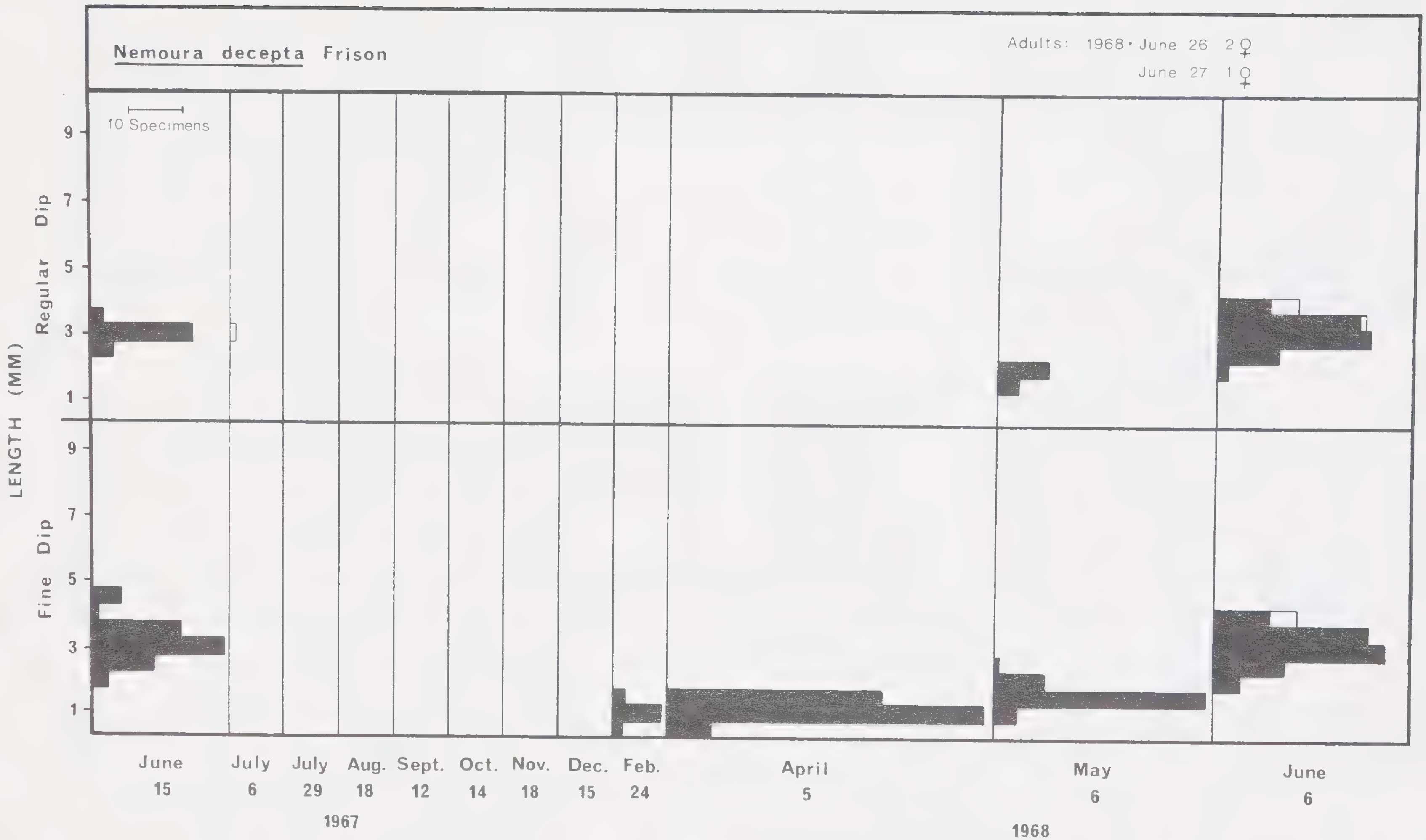
Brachyptera nigripennis (Banks)

Adult specimens of *B. nigripennis* were collected in June and July although no mature nymphs were found at this time (Fig. 16). Hatching occurred during August and September and the new generation grew until October. There was very little growth during the winter, but growth resumed in April, and the nymphs continued to grow rapidly until they emerged in June.

Isogenus (Kogotus) nonus (Needham and Claassen)

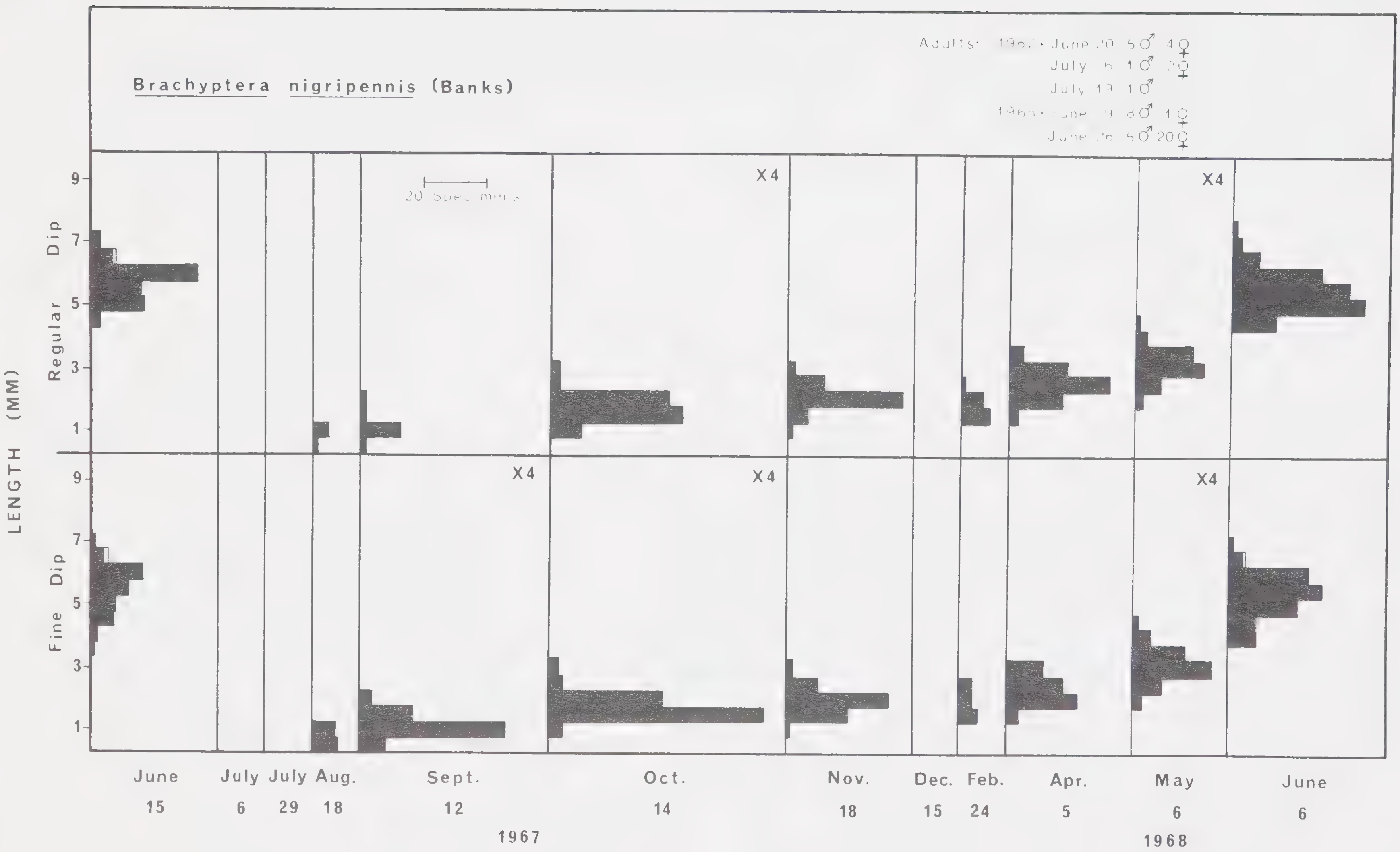
Emergence of *I. nonus* occurred in July and August, followed immediately by the appearance of the new generation (Fig. 17). There was little growth during the summer, and by autumn the nymphs had only reached a maximum size of 3 mm; they did not grow in winter. Growth resumed in spring and accelerated rapidly during June and July, the nymphs growing

Fig. 15. Length-frequency histogram of *Nemoura decepta*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence.



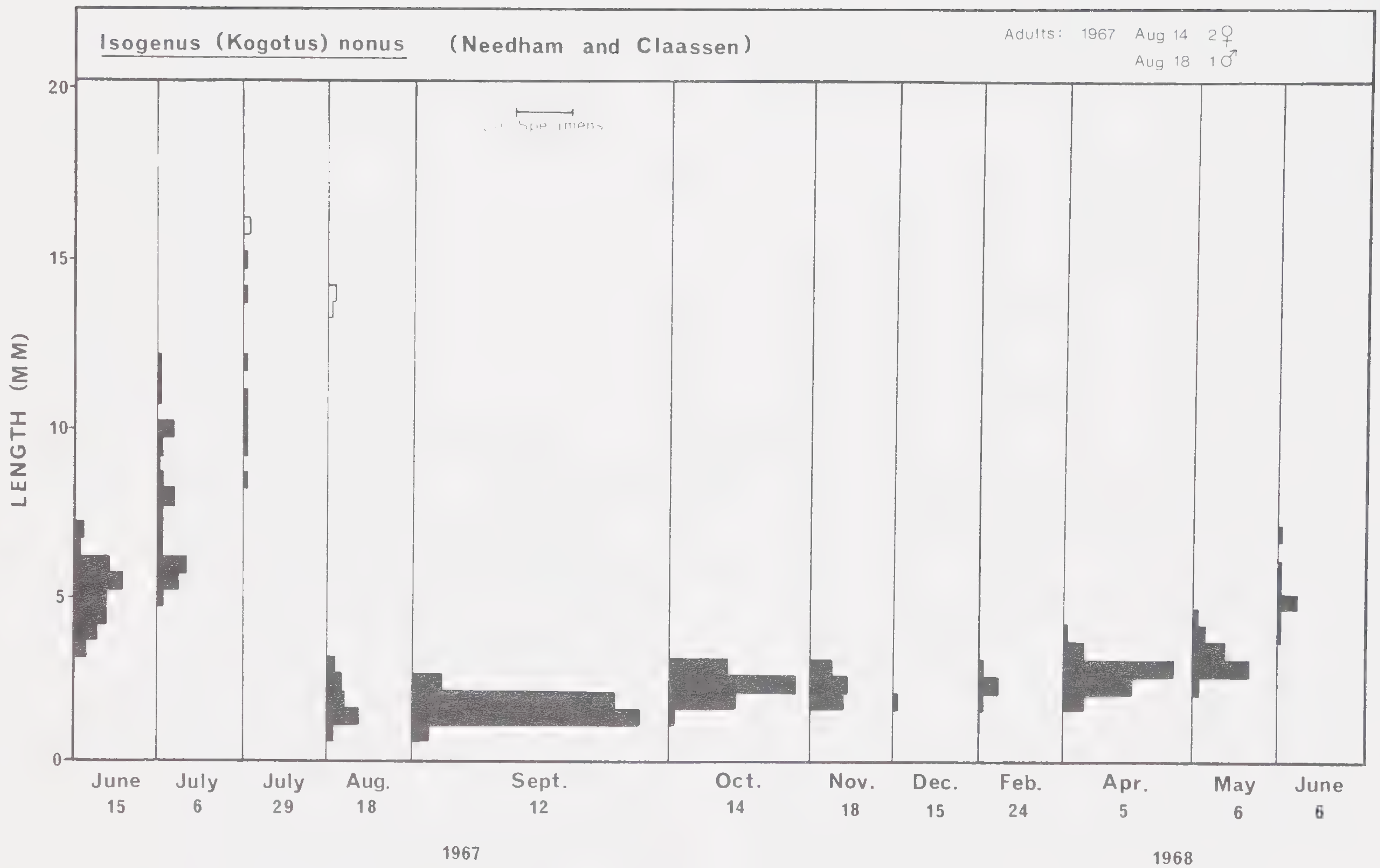
Nemoura decepta Frison
Adults: 1968 • June 26 2♀
June 27 1♀
10 Specimens
LENGTH (MM)
Regular Dip
Fine Dip
9
7
5
3
1
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
April 5
May 6
June 6
1967
1968

Fig. 16. Length-frequency histogram of *Brachyptera nigripennis*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence.



Brachyptera nigripennis (Banks)
Adults: 1967: June 20 5♂ 4♀
July 5 1♂ 2♀
July 19 1♂
1968: June 9 8♂ 1♀
June 26 5♂ 20♀
20 Specimens
X4
LENGTH (MM)
Regular Dip
Fine Dip
9
7
5
3
1
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

Fig. 17. Length-frequency histogram of *Isogenus nonus*. Unshaded bar represents nymphs with darkened wing pads indicating impending emergence. Collections with both fine and regular meshed dip nets combined.


Isogenus (Kogotus) nonus (Needham and Claassen)
Adults: 1967 Aug 14 2♀
Aug 18 1♂
LENGTH (MM)
20
15
10
5
0
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

13 mm in 4 months.

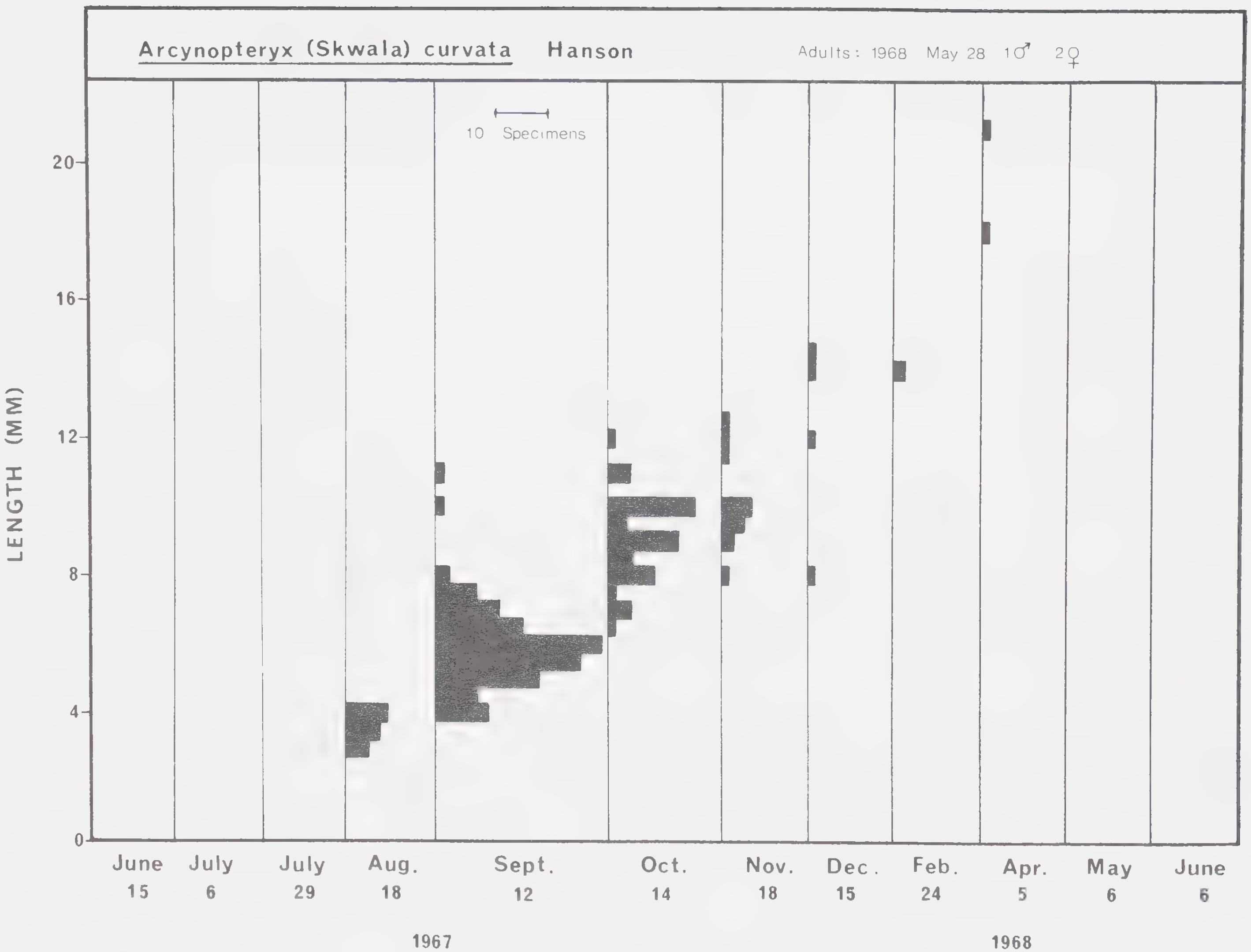
Arcynopteryx (Skwala) curvata Hanson

Adults of *A. curvata* were collected in late May with the new generation first appearing in August (Fig. 18). Although few specimens were collected in the winter, it appeared that this species may continue to grow throughout the winter months.

Acroneuria pacifica Banks

It was difficult to accurately interpret the life cycle of *A. pacifica* (Fig. 19). The composite nature of the population could be the result of a long period of egg hatching, retarded growth of many nymphs, the development of the species over more than one year, or a combination of these (Brinck, 1949). The presence of small nymphs in all samples could be explained by a long period of hatching or retarded development. After one year of development, growth appeared to accelerate resulting in a population having a wide range of sizes and no distinct grouping. Since mature nymphs were about 30 to 35 mm in length, it is possible that more than one year is required to complete the life cycle. More conclusive evidence might be obtained if head capsule width or wing pad development was measured; either of these might effectively group the specimens of varying total length into the same developmental stage. Development requiring more than one year has been documented for *Steoperla prasina* (Helson, 1934), *Pteronarcys proteus* (Miller, 1939) and an Eustheniidae from Australia (Hynes, 1964).

Fig. 18. Length-frequency histogram of *Arcynopteryx curvata*. Collections with fine and regular meshed dip nets combined.



Arcynopteryx (Skwala) curvata Hanson
Adults: 1968 May 28 1♂ 2♀
10 Specimens
LENGTH (MM)
0
4
8
12
16
20
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

Fig. 19. Length-frequency histogram of *Acroneuria pacifica*. Collections with fine and regular meshed dip net combined.

Acroneuria pacifica Banks
Adults: 1967 July 19 1♂
July 20 1♂ 2♀
20 Specimens
LENGTH (MM)
35
30
25
20
15
10
5
4
3
2
1
June 15
July 6
July 29
Aug. 15
Sept. 12
Oct. 19
Nov. 18
Dec. 15
Feb. 24
Apr. 5
May 6
June 6
1967
1968

STREAM COMMUNITY COMPOSITION

Percentage composition by numbers

"Total" fauna

Table 5 gives the number of animals of various orders collected with the regular meshed dip net and the fine meshed dip net during the period 15 June 1967 to 6 June 1968. On a seasonal basis, direct comparisons of absolute numbers cannot be made, since there may be differences due in part to inefficiency of sampling. For example, the small number of animals collected in winter may have been due to a lower population density at this time, but the physical difficulties encountered with winter sampling were undoubtedly important as well. Likewise the large number of animals collected in September and October, when the water level was low, was in part probably due to sampling bias. To eliminate the bias due to sampling inefficiency, absolute numbers of each order were converted to a percentage of the total of the five orders (Table 5).

Mayflies were the dominant group of Wampus Creek; for most of the year Ephemeroptera made up at least 50 per cent of the "total" fauna. Maximum percentages were in May, June and September with minimum values in December and February. Stoneflies, in contrast to mayflies, made up a more stable although smaller part of the "total" fauna. The maximum percentage for Plecoptera was 29 per cent in May. Diptera (predominately Orthocladinae) contributed a variable amount to the total fauna, maximum values being 33 and 59 per cent in December and February respectively. These high values were probably absolute increases, but they might also have been due to inefficient sampling of other orders at this time,

TABLE 5. Number of specimens of five major orders of aquatic insects collected during the sampling period June 1967 to June 1968, with the percentage of the total in brackets

	Sampling dates											
	1967								1968			
	6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	2-24	4-5	5-6	6-6
Regular meshed dip net												
Ephemeroptera	1664 (83)	3557 (84)	2094 (77)	1840 (69)	1425 (64)	1803 (56)	1098 (75)	No sample	402 (52)	431 (44)	998 (68)	769 (58)
Plecoptera	177 (9)	134 (3)	235 (9)	180 (7)	304 (14)	917 (29)	242 (17)		157 (20)	337 (34)	388 (26)	412 (31)
Trichoptera	38 (2)	82 (2)	73 (3)	118 (4)	109 (5)	166 (5)	30 (2)		24 (3)	88 (9)	32 (2)	45 (3)
Diptera	8	365 (9)	160 (6)	176 (7)	46 (2)	104 (3)	42 (3)		173 (23)	124 (12)	55 (4)	56 (4)
Coleoptera	114 (6)	108 (2)	148 (5)	341 (13)	324 (15)	214 (7)	45 (3)		14 (2)	9 (1)	4	39 (3)
Total	2001	4246	2710	2655	2208	3204	1457		769	989	1477	1321
Fine meshed dip net												
Ephemeroptera	1759 (81)	3642 (81)	1282 (60)	1786 (66)	3525 (72)	2731 (66)	1501 (73)	448 (48)	142 (20)	1715 (62)	936 (56)	1243 (60)
Plecoptera	193 (9)	300 (7)	266 (12)	265 (10)	924 (19)	927 (22)	426 (21)	75 (8)	109 (16)	423 (15)	480 (29)	443 (21)
Trichoptera	49 (2)	95 (2)	80 (4)	162 (6)	170 (3)	118 (3)	24 (1)	53 (6)	26 (4)	100 (4)	55 (3)	46 (2)
Diptera	32 (2)	370 (8)	400 (19)	110 (4)	51	244 (6)	63 (3)	306 (33)	412 (59)	453 (16)	197 (12)	291 (14)
Coleoptera	130 (6)	93 (2)	116 (5)	374 (14)	210 (4)	95 (2)	52 (2)	44 (15)	12 (2)	63 (2)	3	46 (2)
Total	2163	4500	2149	2697	4880	4115	2066	926	701	2754	1671	2069

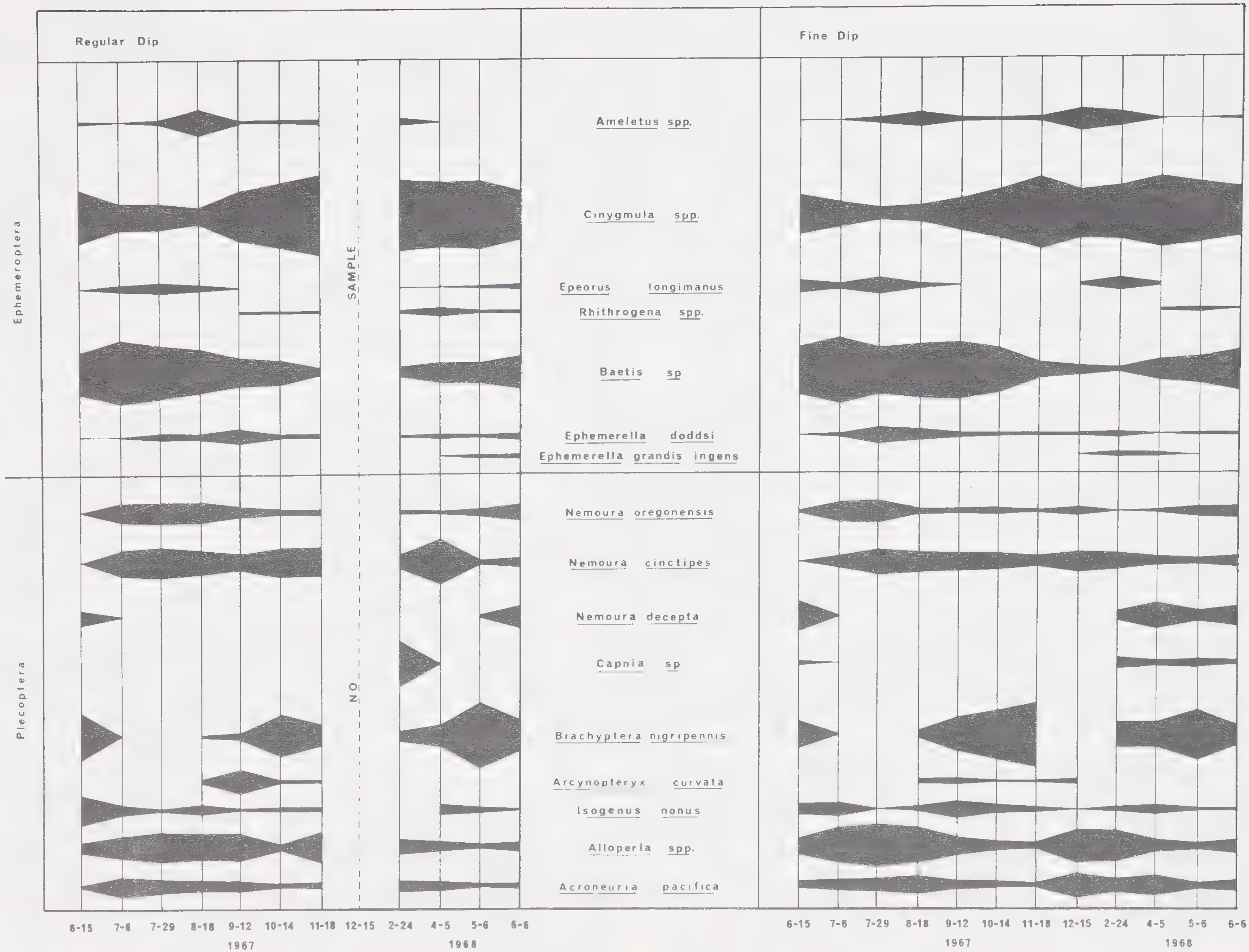
especially Ephemeroptera.

Percentage composition values can be misleading; variation could be due to an absolute increase in the number of animals of one species or to an absolute decrease in the number of other organisms. To overcome these "interspecific" influences, especially between species of different orders, percentage composition of species within the same order was also determined.

Ephemeroptera

Each of seven species of Ephemeroptera contributed values greater than 2 per cent of the total mayfly fauna (Fig. 20). The greatest contribution was by *Baetis* sp. and by the species of *Cinygmula*. In June, the dominant mayfly was *Baetis* sp. with *Cinygmula* spp. next in abundance. In early July *Baetis* sp. had increased, probably as a result of the influx of the summer generation. The decrease of *Baetis* in the latter part of July could be correlated with its emergence at this time and hence the loss of the winter generation. The interpretation of the *Cinygmula* spp. is complicated by inability to differentiate the species present; however, the decreasing values during July and August were probably the result of emergence. A similar decrease also occurred for *Epeorus longimanus*, which had the same type of emergence pattern as *Cinygmula* spp. The gradual increase in numbers during August and September by *Baetis* sp. was probably the result of summer hatching. By August, the *Cinygmula* complex also began increasing in numbers due to hatching of the new generation. The number of *Cinygmula* continued to increase through September and October, making *Cinygmula* the dominant winter mayfly. The *Baetis* population decreased in autumn due to the loss of the summer generation, and the winter generation contributed only a minor part to the winter mayfly fauna.

Fig. 20. Percentage composition in numbers of Ephemeroptera and Plecoptera collected with regular dip and fine dip nets from 15 June 1967 to 6 June 1968. Width of spindle is proportional to the total numbers of each order collected on the sampling date.


Regular Dip
Fine Dip
Ephemeroptera
Plecoptera
Ameletus spp.
Cinygmula spp.
Epeorus longimanus
Rhithrogena spp.
Baetis sp
Ephemerella doddsi
Ephemerella grandis ingens
Nemoura oregonensis
Nemoura cinctipes
Nemoura decepta
Capnia sp
Brachyptera nigripennis
Arcynopteryx curvata
Isogenus nonus
Alloperla spp.
Acroneuria pacifica
SAMPLE
NO
6-15
7-6
7-29
8-18
9-12
10-14
11-18
12-15
2-24
4-5
5-6
6-6
1967
1968

Plecoptera

Throughout the year, the plecopteran fauna contributed a small but consistent percentage of the "total" fauna. There were seven species and one "species-complex" mainly contributing to the stonefly fauna (Fig. 20). A dominance status was not applicable to any one species, since each species occurred only in small numbers. During the summer, *Nemoura cinctipes* and the *Alloperla* complex contributed the greatest numbers. With the recruitment of the new generation of *Brachyptera nigripennis* in August and September, this species became dominant. During the winter, *Nemoura cinctipes* and *Brachyptera nigripennis* formed the major part of the stonefly population, with *Nemoura decepta* appearing and becoming important in late winter.

Percentage composition by volume-biomass

"Total" fauna

Ephemeroptera was the dominant group by percentage volume-biomass, as well as numbers (Table 6). Mayflies, on a relative basis, achieved their greatest biomass values in July (37%) and December (70%). In general, the contribution to volume-biomass by plecopterans was higher than their contribution to numbers. This would be expected, since stoneflies, especially some of the setipalpian specimens, grow to a larger size than mayflies. Trichoptera, Diptera, and Coleoptera contributed little to the biomass structure of the stream community.

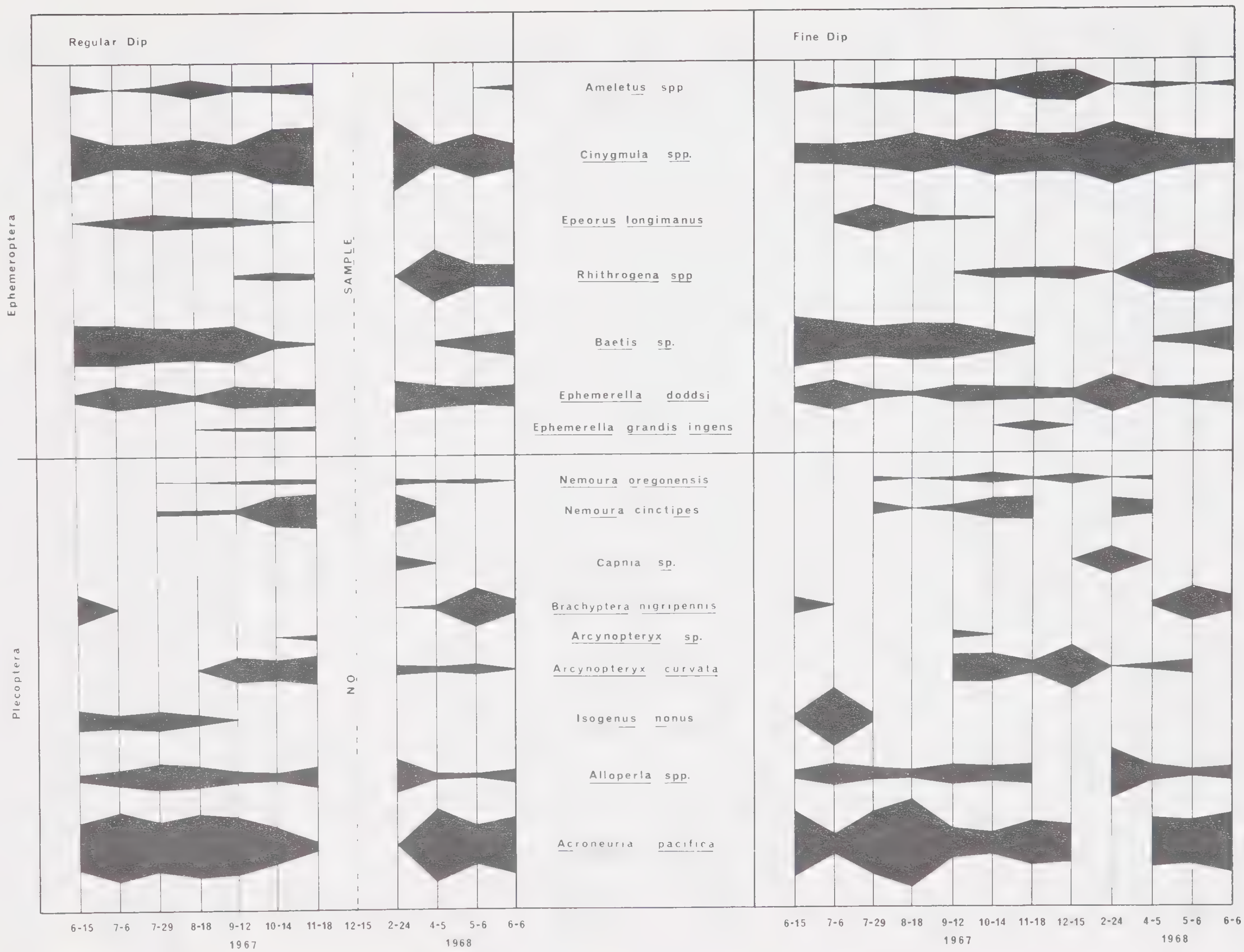
Ephemeroptera

Cinygmula spp. and *Baetis* sp., because of their large numbers, made the greatest contribution to the volume-biomass (Fig. 21). In spring, *Baetis* nymphs contributed the greatest biomass. *Ephemerella*

TABLE 6. Volume-biomass (cc) of the five major orders of aquatic insects collected during the sampling period June 1967 to June 1968, with the percentage of total in brackets

	Sampling dates											
	1967								1968			
	6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	2-24	4-5	5-6	6-6
Regular meshed dip net												
Ephemeroptera	4.49 (71)	11.09 (80)	9.48 (72)	6.02 (62)	2.58 (34)	5.15 (45)	3.12 (67)	No sample	0.20 (25)	0.90 (28)	2.48 (74)	4.27 (63)
Plecoptera	1.39 (22)	1.71 (12)	3.03 (23)	2.49 (26)	3.23 (42)	4.18 (37)	1.16 (25)		0.59 (73)	2.20 (68)	0.82 (24)	2.18 (32)
Trichoptera	0.13 (2)	0.46 (3)	0.32 (3)	0.62 (6)	0.62 (8)	0.54 (5)	0.09 (2)		0.02 (2)	0.10 (3)	0.03 (1)	0.18 (3)
Diptera	0.08 (2)	0.45 (3)	0	0.30 (3)	0.81 (11)	1.40 (12)	0.26 (6)		0	0.01 (1)	0.02 (1)	0.16 (2)
Coleoptera	0.21 (3)	0.18 (2)	0.20 (2)	0.30 (3)	0.39 (5)	0.18 (1)	0		0	0	0	0.02
Total	6.30	13.89	13.03	9.73	7.63	11.45	4.63		0.81	3.21	3.35	6.81
Fine meshed dip net												
Ephemeroptera	2.20 (59)	12.95 (87)	3.76 (81)	5.21 (57)	2.84 (56)	4.19 (53)	2.50 (63)	0.85 (70)	0.13 (27)	1.09 (41)	2.60 (64)	4.27 (63)
Plecoptera	1.32 (36)	1.19 (7)	0.86 (18)	1.85 (20)	1.37 (27)	3.03 (38)	1.25 (32)	0.27 (22)	0.24 (49)	1.26 (48)	1.37 (34)	2.18 (32)
Diptera	0	0.40 (3)	0	0.92 (10)	0.15 (3)	0.25 (3)	0.10 (2)	0.08 (7)	0.08 (16)	0.10 (4)	0.05 (1)	0.17 (2)
Trichoptera	0.12 (3)	0.22 (2)	0	0.93 (10)	0.46 (9)	0.35 (4)	0.10 (2)	0.01 (1)	0.04 (8)	0.18 (7)	0.05 (1)	0.18 (3)
Coleoptera	0.08 (2)	0.06 (1)	0.04 (1)	0.27 (3)	0.24 (5)	0.08 (2)	0	0	0	0.01	0	0.02
Total	3.72	14.81	4.66	9.28	5.06	7.90	3.95	1.21	0.49	2.65	4.07	6.82

Fig. 21. Percentage composition by volume-biomass of Ephemeroptera and Plecoptera collected with regular dip and fine dip nets, 15 June 1967 to 6 June 1968. Width of spindle is proportional to the total volume-biomass of each order collected on the sampling date.



Regular Dip
Fine Dip
Ephemeroptera
Plecoptera
Ameletus spp
Cinygmula spp.
Epeorus longimanus
Rhithrogena spp
Baetis sp.
Ephemerella doddsi
Ephemerella grandis ingens
Nemoura oregonensis
Nemoura cinctipes
Capnia sp.
Brachyptera nigripennis
Arcynopteryx sp.
Arcynopteryx curvata
Isogenus nonus
Alloperla spp.
Acroneuria pacifica
NO SAMPLE
6-15 7-6 7-29 8-18 9-12 10-14 11-18 12-15 2-24 4-5 5-6 6-6
1967 1968

doddsi, the largest mayfly nymph of the stream, also contributed significantly to the spring biomass. In early July, *Baetis* sp. were emerging with a resultant decrease in biomass. At this time *E. doddsi* nymphs were reaching maturity and thus increasing in volume-biomass. By the latter part of July, most of *Baetis* sp. and *E. doddsi* had emerged; at this time *Epeorus longimanus* nymphs were larger and they contributed importantly to volume-biomass. In respect to volume-biomass, *Cinygmula* spp. was the dominant winter mayfly.

Plecoptera

The seasonal percentage composition by volume-biomass of plecopterans showed little resemblance to their seasonal percentage composition by numbers (Fig. 21). The percentage composition by numbers was dominated by filipalpian species. Even though the filipalpian species occurred in greater numbers than the setipalpian species, they were not as important in terms of volume-biomass as the large setipalpian species. On a biomass basis, *Acroneuria pacifica*, which attained a length of 35 mm, was the dominant stonefly throughout the year.

STANDING CROP

The advantages and limitations of the Surber-type square foot sampler are well known. Leonard (1939) examined numerous samples from a uniform bottom type and concluded that one sample may yield a reasonably accurate index of the amount of food organisms produced per unit area of uniform bottom type, but one sample cannot provide a comprehensive picture of the relative numbers of individual species from an area larger than that from which the sample was collected. Needham and Usinger

(1956) calculated that 194 ft^2 samples would be required to give statistically significant figures on total weights of organisms, and 73 samples would be necessary to give statistically significant figures on total numbers. Armitage (1958) provided further statistical evidence that the Surber sampler was not quantitative. In spite of these problems associated with the Surber sample, the "quantitative" data were still important for the watershed study because it was felt that land use in the Wampus Creek watershed might alter the standing crop. Collections made after land use (i.e. pulpwood extraction) could be compared with the standing crop values obtained in the present study (i.e. before land use).

During the sampling period, Wampus Creek had an average of 190 organisms per ft^2 ($2047/m^2$) and an average volume of 0.33 cc per ft^2 (3.55 cc/m^2) (Table 7). The number of organisms per m^2 was less than the $7100/m^2$ recorded by Robertson (1967) and the $4568/m^2$ found by Gaufin (1959); but it was somewhat higher than the maximum number of $1296/m^2$ reported by Clifford (1966*b*) for some Ozark streams of southern Missouri and the $1002/m^2$ determined by Tebo and Hassler (1961) for western North Carolina trout streams. The average volume of 3.55 cc/m^2 found in Wampus Creek was slightly lower than the 4.95 cc/m^2 calculated by Tebo and Hassler (1961).

TABLE 7. Standing crop by numbers and volume-biomass for each sampling date, using the fine meshed Surber sampler

	Sampling date										
	1967							1968			
	6-15	7-6	7-29	8-18	9-12	10-14	11-18	4-5	5-6	6-6	Mean
Number/ft.^{2}	74	119	108	109	210	269	240	302	249	224	190
Number/m^2	796	1279	1161	1172	2258	2892	2580	3246	2677	2408	2047
Volume/ft.^{2}	0.14	0.36	0.29	0.23	0.18	0.47	0.24	0.49	0.43	0.47	0.33
Volume/m^2	1.50	3.87	3.12	2.47	1.94	5.05	2.58	5.27	4.62	5.05	3.55

SAMPLING EFFICIENCY

Life histories and mesh size efficiency

To examine the importance of mesh size for collecting and analyzing life histories of aquatic insects, it was necessary to select species that exhibited simple life cycles; e.g. species with one generation a year, without delayed hatching and without overlapping generations. *Ephemerella doddsi*, *Nemoura decepta* and *Brachyptera nigripennis* satisfied these criteria and they were used for this examination.

To statistically compare the efficiency of the fine and regular meshed dip nets, the chi-square (χ^2) test for independence was used. This statistic is used to test the hypothesis that two or more samples are drawn from the same multinomial population (Li, 1964). A multinomial population is a set of observations that can be classified into a number of categories. When a random sample is drawn from a population each category will contain certain observed frequencies. If another random sample is taken from the same population, the resultant observed frequencies should be similar to the frequencies observed in the first sample, provided the same population is sampled and the sampling technique is the same. Therefore, to apply this test, one must first assume that, even though the regular meshed dip net samples and the fine meshed dip net samples were taken in different areas of the same riffle section, the same aquatic insect population was sampled. That is, with reference to a particular species one should obtain the same size classes. If the frequencies in each size class are similar for each sample, the size class distribution is independent of the mesh size of the sampler. The null hypothesis is that the samples have the same set of relative frequencies; that is, the size class distribution is independent of the

mesh size of the sampler.

This statistic also permits comparisons between samples of unequal totals. Since the hypothetical frequency in this test is calculated from the pooled relative frequency, total absolute numbers need not be the same.

During the life history of *E. doddsi* only one sample (29 July 1967) resulted in a significant χ^2 value (Table 8). In other words, the size class distribution of this sample was not independent of the mesh size of the two samplers. Table 9 shows the calculation of the χ^2 value. Examination of the column (f-h) for the 0.5 and 1.0 mm size classes of the regular meshed dip net sample reveals that this sample had a deficit of small specimens. The resultant χ^2 values for these classes contributed a significant portion to the total χ^2 value. The biological meaning of the significant χ^2 value becomes apparent upon examining the life history of *E. doddsi* (Fig. 7). The 29 July 1967 sample included specimens collected during the hatching period. At this time, large numbers of small specimens were undoubtedly present in the population; this population was sampled with greater efficiency by the fine meshed dip net than by the regular.

Inefficient sampling of small specimens was also determined for *N. decepta*. Small specimens were absent from the regular dip net on 24 February and 5 April and hence no χ^2 calculations were made for these dates. Even when small specimens appeared in the regular dip net sample of 6 May, their relative frequency was different from that obtained by the fine meshed dip net; thus the significant χ^2 value (Table 8).

No significant differences were obtained between the regular mesh and the fine mesh samples during the life history of *B. nigripennis*.

TABLE 8. Comparison of mesh size efficiency during the life cycle of *Ephemerella doddsi*, *Nemoura decepta*, and *Brachyptera nigripennis* as determined by chi-square analysis

		Calculated χ^2	Theoretical χ^2	Conclusion
E. doddsi				
1967	7-29	48.08	11.3 (3df)	Significantly different
	8-18	4.12	13.3 (4df)	Not significantly different
	9-12	3.64	15.1 (5df)	"
	10-14	2.30	15.1 (5df)	"
	11-18	3.95	15.1 (5df)	"
1968	2-23	2.40	13.3 (4df)	"
	4-5	7.00	15.1 (5df)	"
	5-6	5.20	16.8 (6df)	"
	6-6	4.70	20.1 (8df)	"
N. decepta				
1967	6-15	9.01	15.1 (5df)	Not significantly different
1968	2-24			Significantly different (No specimens collected in regular dip)
	4-5			"
	5-6	12.20	11.3 (3df)	Significantly different
	6-6	1.04	13.3 (4df)	Not significantly different
B. nigripennis				
1967	6-15	9.70	18.5 (7df)	Not significantly different
	8-18	3.43	6.6 (1df)	"
	9-12	6.04	11.3 (3df)	"
	10-14	7.66	13.3 (4df)	"
	11-18	10.59	13.3 (4df)	"
1968	2-23	7.64	11.3 (3df)	"
	4-5	9.75	13.3 (4df)	"
	5-6	2.65	15.1 (5df)	"
	6-6	7.79	18.5 (7df)	"

TABLE 9. Calculations for χ^2 value for comparison of mesh size efficiency in 29 July 1967 sample of *E. doddsi*

	Class	Observed Frequency (f)	Hypothetical Frequency (h)	(f-h)	$(f-h)^2$	$\frac{(f-h)^2}{h}$
Regular Dip Net	0.5	0	4	-4.0	16	4.00
	1.0	5	21	-16.0	256	12.19
	1.5	92	80	12.0	144	1.80
	2.0	14	6	8.0	64	10.66
Fine Dip Net	0.5	12	89	4.0	16	2.00
	1.0	56	40	26.0	676	6.40
	1.5	138	150	-28.0	784	5.22
	2.0	3	11	-8.0	64	5.81
					Calculated χ^2 =	48.08
					Theoretical $\chi^2_{0.010}$ (3df) =	11.30

Although the number of nymphs collected in the regular dip net was small, the regular dip net always collected specimens with size class distributions similar to those of the fine meshed dip net. This might be due, at least in part, to the morphology of the nymphs. They had antennae that were disproportionately long in relation to body length (Fig. 22). Thus, a morphological feature could explain the significant efficiency of the regular meshed net.

Body shape and mesh size efficiency

The composite sampler provided an opportunity to examine the relationship between the body shape of nymphs and the efficiency of mesh size (Table 10). Specimens of *Nemoura cinctipes* and *Epeorus longimanus* longer than 2.0 mm did not pass through the regular mesh. However, *Baetis* nymphs smaller than 3.5 mm and *Paraleuctra* nymphs up to 4.5 mm in length did pass through the regular mesh. This difference in efficiency might be explained by the body shape of the species. *N. cinctipes* was cylindrical, robust, and hairy; *E. longimanus* was flattened, while *Baetis* sp. and *Paraleuctra* sp. were cylindrical and streamlined (Fig. 23). *N. cinctipes* and *E. longimanus* had a greater over-all width than did *Baetis* sp. and *Paraleuctra* sp. Thus, mesh size efficiency might best be expressed in terms of the maximum width rather than the body length of the specimens.

Number and volume-biomass of different meshed dip nets

For the five major orders of aquatic insects, the regular and fine meshed dip nets were compared in terms of percentage numbers and percentage volume-biomass (Figs. 24,25). Except for some minor differences, the results were surprisingly similar. Also, both the regular and fine meshed dip nets collected a similar type fauna. For example,

Fig. 22. Dorsal view of *Brachyptera nigripennis*; note long antennae. (X 15)

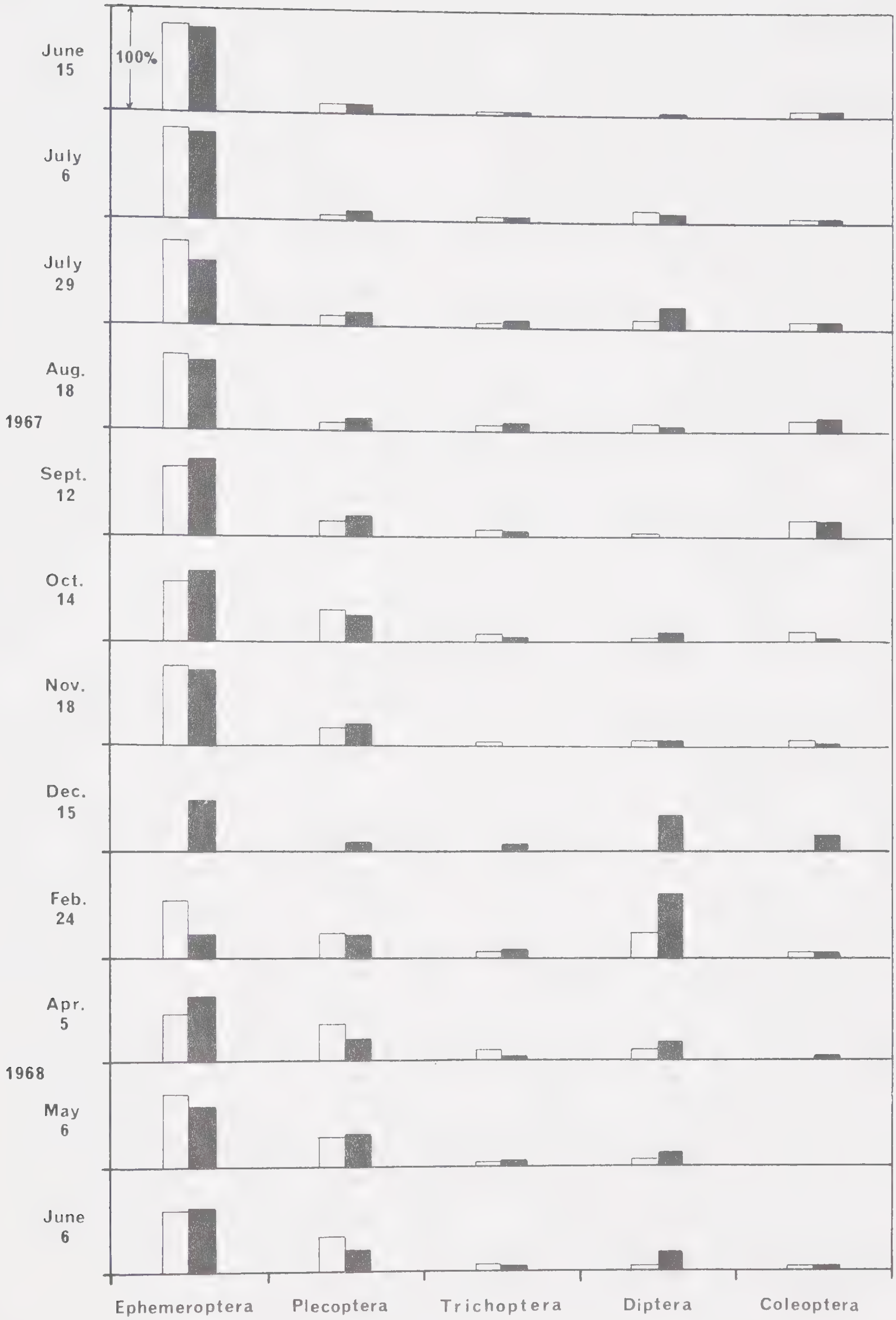
TABLE 10. Comparison of body shape of organisms and mesh size efficiency

Species	Size class (mm)	Number in regular mesh of composite dip net	Number in fine mesh of composite dip net	Total	Percentage that passed through regular mesh net	Body shape (see Fig. 23)
Nemoura cinctipes	1.0	0	3	3	100	Cylindrical, robust
	1.5	23	22	45	49	
	2.0	37	11	47	23	
	2.5	6	0	6	0	
Epeorus longimanus	0.5	0	23	23	100	Flattened
	1.0	0	53	53	100	
	1.5	9	16	25	64	
	2.0	13	3	16	19	
	2.5	8	0	8	0	
Baetis sp.	1.0	0	14	14	100	Cylindrical
	1.5	0	39	39	100	
	2.0	7	33	40	83	
	2.5	4	12	16	75	
	3.0	18	5	23	22	
	3.5	14	0	14	0	
Paraleuctra sp.	2.0	0	1	1	100	Cylindrical
	2.5	0	1	1	100	
	3.0	0	5	5	100	
	3.5	0	4	4	100	
	4.0	0	1	1	100	
	4.5	0	3	3	100	

Fig. 23. Comparison of body shape of *Baetis* sp., *Nemoura cinctipes*, *Epeorus longimanus* and *Paraleuctra* sp. (left to right respectively).

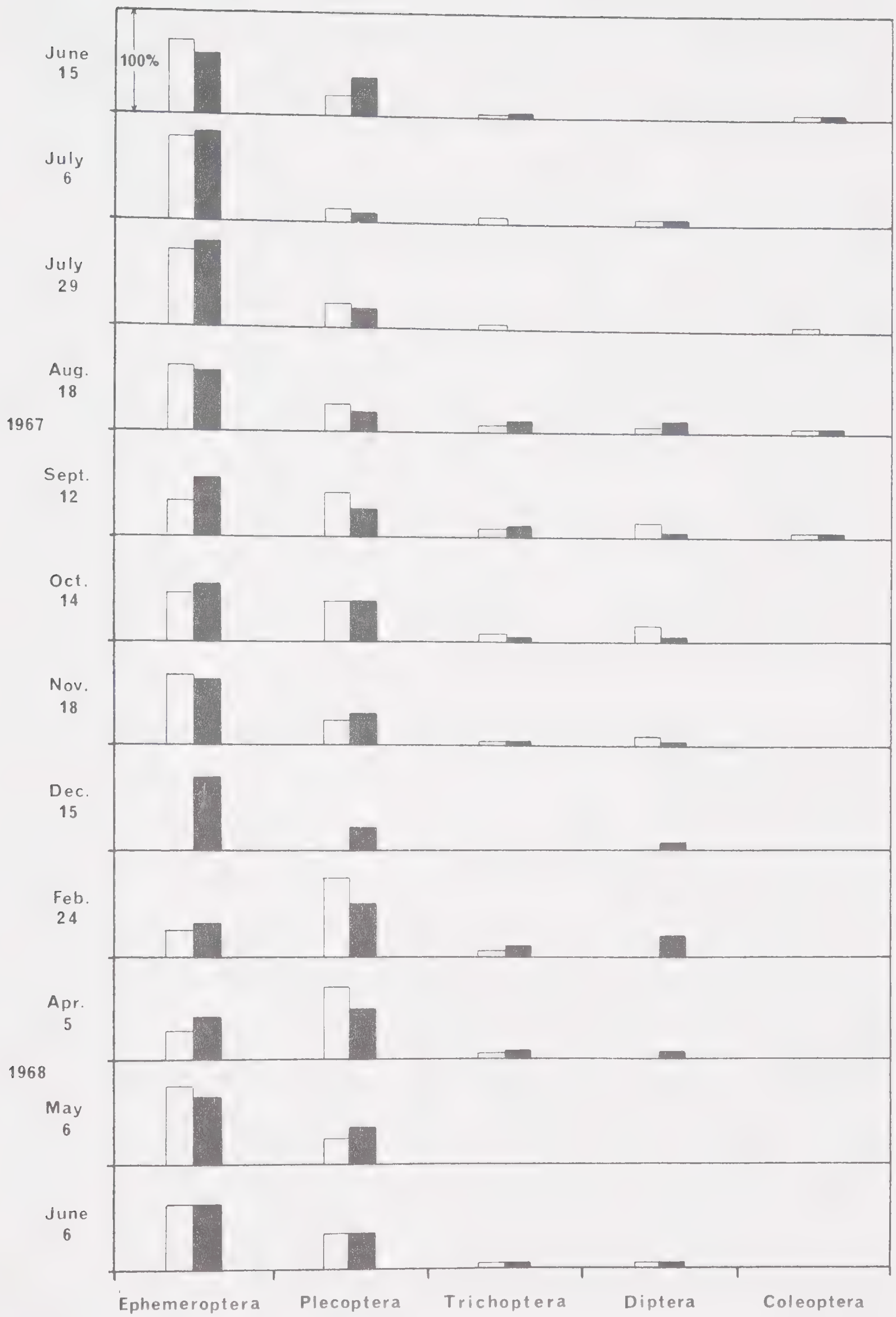
X 15

Fig. 24. Comparison of percentage numbers of various insects collected by regular and fine dip nets. Each order is expressed as a percentage of total number of animals collected on each sampling date. Unshaded bar represents the regular dip net sample. Shaded bar represents the fine dip net sample.



June
15
100%
July
6
July
29
Aug.
18
1967
Sept.
12
Oct.
14
Nov.
18
Dec.
15
Feb.
24
Apr.
5
1968
May
6
June
6
Ephemeroptera
Plecoptera
Trichoptera
Diptera
Coleoptera

Fig. 25. Comparison of percentage volume-biomass of various insects collected by regular and fine dip nets. Each order is expressed as a percentage of total volume of animals collected on each sampling date. Unshaded bar represents the regular dip net sample. Shaded bar represents the fine dip net sample.



100%
June 15
July 6
July 29
Aug. 18
1967
Sept. 12
Oct. 14
Nov. 18
Dec. 15
Feb. 24
Apr. 5
1968
May 6
June 6
Ephemeroptera
Plecoptera
Trichoptera
Diptera
Coleoptera

in terms of numbers collected, *Cinygmula* sp. and *Baetis* sp. were the dominant mayflies in both nets. Similar results were obtained for volume-biomass. In short, on a *relative* basis, both samplers would yield similar results.

To examine the absolute differences in terms of numbers and volume-biomass, the composite sampler was utilized. Table 11 gives the results of one sample, 6 June 1968, taken with the composite dip net sampler. The percentage of organisms passing through the regular mesh was high for Ephemeroptera, Plecoptera, and Diptera (45%, 29%, and 84% respectively). Since only small specimens passed through the regular mesh, the loss in terms of volume-biomass was low; e.g. 4% for Ephemeroptera, 1% for Plecoptera, and 6% for Diptera. The biological implications of these results will be dealt with in the Discussion.

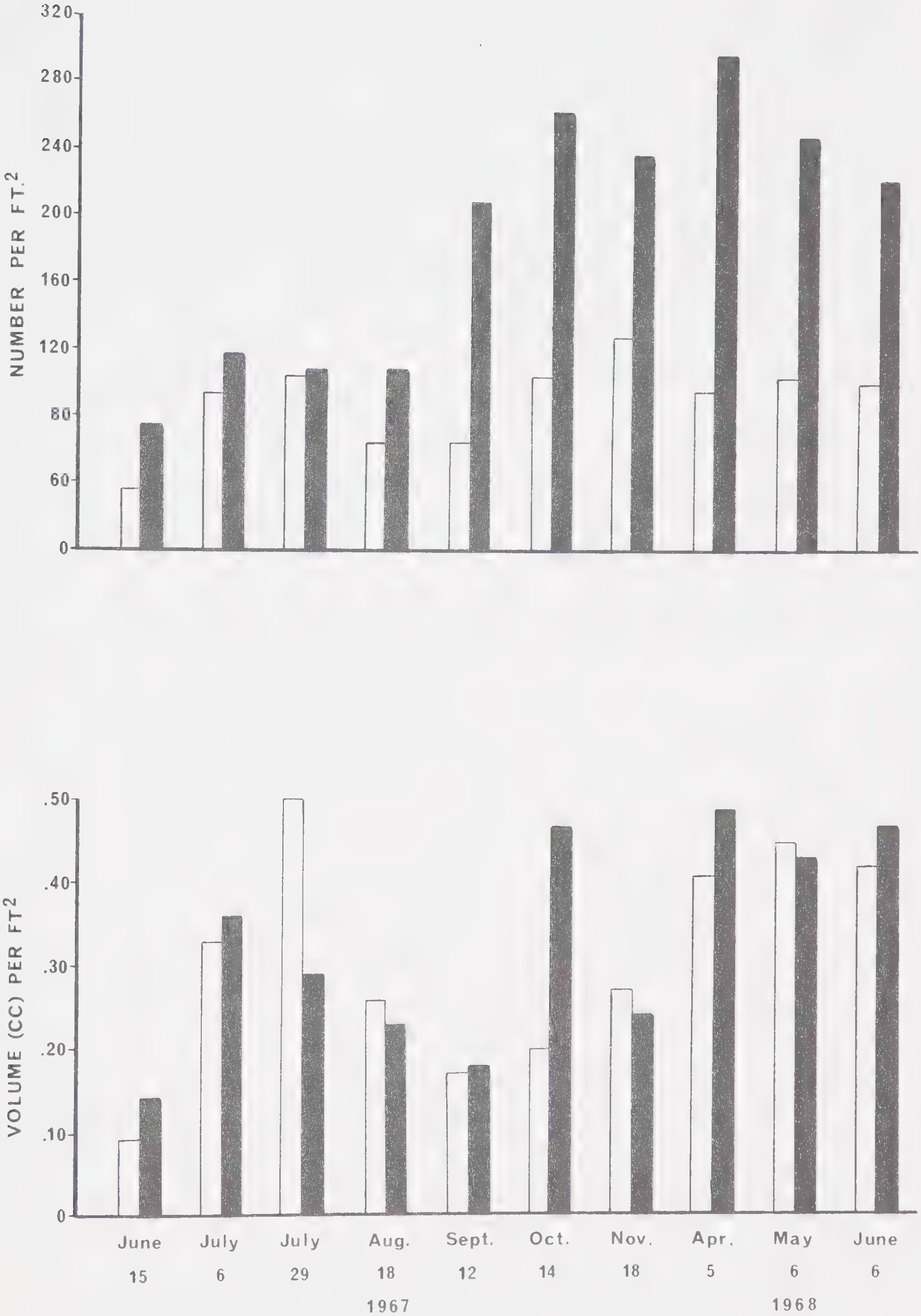
Number and volume-biomass of different meshed Surber samplers

A comparison of number and volume-biomass obtained by the regular and fine meshed Surber sampler is given in Fig. 26. In all samples, the number of organisms per ft^2 collected by the fine meshed Surber was greater than that collected by the regular meshed Surber. Since the samples were taken close together, the differences cannot be explained by "clumped" distribution for the probability of consistently sampling the "clumped" distribution with the fine meshed Surber and not the regular meshed Surber would be very high (especially with 10 replications). In contrast to the results for number of organisms, the data on volume-biomass, expressed as cc/ft^2, did not show great differences (Fig. 26), except for 29 July and 14 October. For these two samples, the differences were largely due to the presence or absence of

TABLE 11. Comparison of efficiency of mesh-size in composite dip net sample, 6 June 1968

Order	Regular mesh of composite dip net	Fine mesh of composite dip net	Total in composite sample	Percentage of total passing through regular meshed dip net
Numbers				
Ephemeroptera	769	629	1398	45
Plecoptera	412	168	580	29
Trichoptera	45	1	46	2
Coleoptera	39	7	46	15
Diptera	56	291	347	84
Volumes (in cc)				
Ephemeroptera	4.27	0.20	4.47	4
Plecoptera	2.18	0.02	2.20	1
Trichoptera	-	-	-	-
Coleoptera	-	-	-	-
Diptera	0.16	0.01	0.17	6

Fig. 26. Comparison of numbers and volume-biomass of organisms collected with regular and fine meshed Surber samplers. Unshaded bar represents regular Surber sample. Shaded bar represents fine Surber sample.


320
280
240
200
160
120
80
60
0
NUMBER PER FT.^{2}
.50
.40
.30
.20
.10
0
VOLUME (CC) PER FT^2
June 15
July 6
July 29
Aug. 18
Sept. 12
Oct. 14
Nov. 18
Apr. 5
May 6
June 6
1967
1968

of large specimens of the stonefly *Acroneuria pacifica*. If these large specimens were removed, the volume-biomass collected by each mesh would be virtually the same.

The problem of possibly not sampling the same population was avoided by using the composite Surber sample. Since the same population was sampled, the difference in numbers would be the result of differences in mesh size. The composite Surber sample provided conclusive evidence that the differences in numbers were due to mesh size (Table 12). The number of organisms that passed through the regular mesh was high for each order; the biological ramifications of these results will be dealt with in the Discussion. In contrast, for volume-biomass the results of the composite Surber sample showed that the differences due to mesh size were small (Table 12).

TABLE 12. Comparison of efficiency of mesh-size in composite Surber sample, 6 June 1968

Order	Regular mesh of composite Surber	Fine mesh of composite Surber	Total in composite sample	Percentage of total passing through regular meshed Surber
Numbers				
Ephemeroptera	335	359	694	52
Plecoptera	161	197	358	55
Trichoptera	21	14	35	40
Diptera	19	40	59	68
Coleoptera	6	14	20	70
Volume-biomass (cc)				
Ephemeroptera	1.41	0.11	1.52	7
Plecoptera	0.62	0.01	0.63	2
Diptera	0.13	0.01	0.18	6

DISCUSSION

Life histories

Species have evolved various types of life histories to adapt to their environment. Macan (1965) classified life histories of aquatic insects into three main groups: (1) *development takes longer than one year;* (2) *one generation in one year* (univoltine), subdivided into (a) "summer species" with eggs laid in early summer, development completed in the summer, and winter passed either in egg or adult stage, (b) "winter species" which overwinter as larvae and disappear from the water or become very scarce during the summer; (3) *more than one generation in a year* (bivoltine). In addition to summer species, Hartland-Rowe (1964) recognized two types of winter species based on growth characteristics: (1) species that hatch in late summer, grow in autumn, do not grow in winter, but resume growing again in spring with development completed in summer; (2) species that hatch in spring, grow in summer, autumn and slowly in winter, and then grow rapidly in spring with emergence also in spring. Pleskot (1962) used the term "temporary species" to describe those species that appear in streams for only a short period each year.

Thirteen of the 15 Wampus Creek species for which there were adequate data had one generation in one year (univoltine); *Baetis* sp. had at least two generations a year, while *Acroneuria pacifica* required more than one year for development. Of the 13 species with univoltine life histories, only *Ephemerella tibialis* was a true summer (temporary) species; the remainder were winter species.

Although the mayflies and stoneflies of Wampus Creek exhibited various types of life histories, the seasonal occurrence of certain life

history processes, such as emergence and growth, were similar for all species (Table 13). Clifford (1969) contrasted the restricted emergence period of the fauna of the Bigoray River (Alberta) with longer emergence periods in streams where winters were shorter and milder (Hynes, 1961; Kraft, 1964; Peters and Warren, 1966) or remained open in winter because of a steep gradient (Sheldon and Jewett, 1966). In Wampus Creek, emergence of all species except *Epeorus longimanus*, *Baetis* sp. and *Nemoura cinctipes* was confined to the period May to August. This undoubtedly reflects the physical and climatic factors of this area. Water temperatures restricted the emergence period to the summer months. Since all species (for which life histories were described) have aerial adults, the long period of ice cover will limit emergence to the ice-free period, a relatively short period in the Wampus Creek region.

The possible relationship of temperature to growth phases of aquatic insects has been discussed by several workers. Illies (1952) advocated the "Entwicklungsnullpunkt" theory for nymphal growth: as the temperature of the stream gradually falls in the autumn, growth at a critical low temperature, the so-called "Entwicklungsnullpunkt", ceases for each species. In spring, growth will resume when the temperature exceeds the critical point. Hynes (1961) and Illies (1952) found that the growth rates of plecopteran nymphs in their respective study areas, Britain and southern Sweden, were very little affected by low winter water temperatures. Winter conditions in their areas are not severe. For Scandinavian waters, Brink (1949) found the growth rate of stoneflies changed considerably with latitude; colder climates resulting in retarded growth rates. Svensson (1966) reported decreased growth with decreasing water temperature for stoneflies of northern Sweden. For Wampus Creek,

TABLE 13. Life cycle patterns of the mayflies and stoneflies of Wampus Creek

	Emergence	Egg stage	Hatching	Growth	Life cycle type
Ephemeroptera					
Ephemerella doddsi	July	July	July	S,A,Sp	univoltine
Ephemerella grandis ingens	July	July	July	S,A,Sp	univoltine
Ephemerella inermis	July	July	July-Aug	S,A,Sp	univoltine
Ephemerella coloradensis	July-Aug	Aug	Nov	Sp	univoltine
Ephemerella tibialis	Aug	Aug-July	July	S	univoltine
Epeorus longimanus	July-Oct	Aug-Oct	Dec	Sp,S	univoltine
Rhithrogena spp.	July-Aug	July-Aug	Aug	S,A,Sp	univoltine
Baetis sp.					
winter generation	May-June	Sept	Sept-Nov	?W,Sp	bivoltine
summer generation	Aug-Sept	June	June	S	
Plecoptera					
Nemoura cinctipes	Apr-June	?Apr-May	?Apr-May	Sp,S,A	univoltine
Nemoura oregonensis	May-June	May	May	S,A	univoltine
Nemoura decepta	June-July	July	Feb	Sp	univoltine
Brachyptera nigripennis	June-July	July	Aug-Sept	A,Sp	univoltine
Isogenus nonus	July-Aug	Aug	Aug	A,Sp	univoltine
Arcynopteryx curvata	May	May-June	Aug	S,A,?W,Sp	univoltine
Acroneuria pacifica	July	July	July-?	?	More than one year

Sp — Spring S — Summer A — Autumn W — Winter ? — Speculative

the increase in size of individuals was greatest in late summer, autumn, and spring, with the possible exception of *Arcynopteryx curvata* (Table 13). This suggests that physical conditions during the winter inhibited growth; e.g. Wampus Creek has an average winter water temperature of about 0.5°C.

The life histories of temperate and especially subarctic stream insects might best be discussed in terms of two seasonal systems: the winter, or "closed", system and the spring-summer-autumn, or "open", system. The presence of an ice cover on Wampus Creek for about 7 months of the year effectively isolates the fauna from the surrounding environment; loss of species from the community as aerial adults during this time is not possible; recruitment of new species is possible only by the delayed hatching of eggs, which would have been oviposited during the ice-free (open) period. Of the 14 species that appeared in the spring, only *Epeorus longimanus* and *Nemoura decepta* did not occur in the autumn samples. These two species appeared during the winter as the result of delayed hatching. In general, the winter period, or "closed" system, was characterized by only minor changes in both numbers and volume-biomasses.

With the disappearance of the ice, the stream becomes an open system. Increasing air temperature results in increasing water temperature. *Nemoura cinctipes* emerged as soon as openings appeared in the ice. During June, July and August, the remainder of the winter generations emerged. The new generations hatched quickly and the nymphs grew rapidly during summer and autumn. The loss of the winter generations by emergence and the appearance of the new generations creates a community with fluctuating numbers and volume-biomasses.

The life histories of the species reflects a delicate balance between the physical environment and the biological community. Undoubtedly the fauna has adapted to the rigorous conditions of this region; it is this balance that might be detrimentally altered when the land is cleared during pulpwood extraction.

One may speculate as to the possible physical changes that might occur as the result of future land use. Some effects of land clearing on the physical environment of streams have already been documented. Logging in steep terrain in the northwestern United States increased turbidity 5,600 times (Hornbeck and Reinhart, 1964). Studies in the Pacific Northwest have shown that clear-cutting, i.e. removing all the timber from large tracts of land, changed the daily water temperature by 8°C, with a mean monthly temperature change of 8°C (Krygier and Brown, 1967). Woodland clearance along a stream in northern England increased the maximum stream temperature from 15°C to 21.5°C (Gary and Edington, 1969). Also, removal of the watershed vegetation will undoubtedly change the annual flow patterns. During the spring, the vegetation inhibits snow melt. With removal of this vegetation, run-off will not be retarded, resulting in much higher spring discharges. The vegetation also acts as a reservoir, storing run-off water. Loss of the upper canopy, namely trees, will probably result in marked changes in run-off from summer rains. Evaporation from the soils will probably increase due to the loss of the upper canopy, which effectively shaded the soil.

What effect might these changes have on the aquatic invertebrate fauna? Since the precise requirements of individual species are not known, discussion of future changes must be restricted to

general statements. Permanent changes in number of species, number of individuals and biomass could result if siltation was intense and of a long duration. If extensive substrate changes took place, drastic shifts from "clean rubble and gravel" aquatic invertebrates to those inhabiting silt would probably occur. If siltation resulted in a decrease of suitable habitats, the species composition might remain the same; however, the numbers and biomass would likely decrease (Wustenberg, 1954; Tebo, 1955, 1957; and Bachman, 1958).

The influence of temperature on growth and emergence of aquatic insects has already been discussed. Unfortunately, few data are available on the temperature tolerance of individual species. Whitney (1939) found lethal temperature values of 22.4° and 24.7°C for populations of *Rhithrogena semicolorata* (Curtis) taken from two streams. The lethal temperature was about 21°C and 28.5°C for *Baetis rhodani* (Pictet) and *Cloeon dipterum* (Linnaeus), respectively. Small specimens were found to be more resistant than larger ones. To document the effect of temperature, it would be necessary to experimentally determine the lethal temperature for each species.

Sampling efficiency

Jonasson (1955) stated that many conclusions pertaining to life histories of insect larvae have been erroneously arrived at because of the use of too large a mesh size. In my study, the interpretation of the life history of *Nemoura decepta* would have been incorrect if only the regular meshed dip net samples were considered. One would have concluded that eggs from this species had remained unhatched from July to the following May; however, the fine meshed dip net samples indicated that the eggs hatched in February and the nymphs remained very small

until May (Fig. 15).

If the life histories of aquatic insects are to be classified accurately into broad groups, it is imperative that conclusions be drawn from samples collected with fine meshed samplers. Admittedly, the life histories for *Epeorus longimanus*, *Nemoura cinctipes*, *Nemoura oregonensis*, and *Brachyptera nigripennis* obtained separately by regular and fine meshed dip nets were very similar; however, if these species had life histories with delayed hatching or more than one generation a year, the fine meshed dip net would have provided more accurate information than the regular meshed dip net.

Macan (1958*a*) reviewed the various methods of sampling the bottom fauna in stony streams. For populations of *Rhithrogena*, he concluded for the 1-2 mm size nymphs that the coarse net (20 threads/inch) collected only 20% of what was collected in the fine net (180 threads/inch) and only 40% of the 2-3 mm size nymphs. For *Baetis*, nearly every specimen under 2 mm passed through the coarse net. In contrast, specimens above the 5-6 mm size group were collected more efficiently with the coarse net. Mackereth (1957) caught more of the large sized specimens of stoneflies in a coarse meshed net than the fine meshed net; however, the fine meshed net caught more of the small sized specimens. In the Wampus Creek study, 83% of *Baetis* sp. in the 2.0 mm size class passed through the regular meshed net; and all the specimens of *Baetis* sp. in the 1.0 and 1.5 mm size classes passed through the regular mesh (Table 10). These percentages cannot be applied to all species, because mesh efficiency varies with the shape of the organism. Flattened specimens such as *Epeorus longimanus* were collected with greater efficiency than the thin, cylindrical specimens of *Paraleuctra* sp.

In energy flow and trophic levels studies, mesh size is very important. The results of the composite Surber sample indicated that from 52-70% of total numbers of organisms in a unit area were missed using the regular meshed net (Table 12). The loss in volume-biomass was 2-7% of the total volume-biomass. Since the small organisms are an integral part of the food web of a community, the absence or presence of large numbers of small specimens could have a marked effect on the trophic structure of the community. By failing to adequately sample these small organisms, their contribution to the food web is ignored. For Allen's (1961) study of the Horokiwi Stream, this may in part explain the discrepancy between the standing crop of invertebrates and the amount that had to be eaten by trout to account for the productivity of the trout. The small stages of aquatic insects were probably very important as food organisms for young trout fry; and hence would contribute to the productivity of the trout. Since these organisms were not sampled, their contribution to the productivity of the stream was not considered.

LITERATURE CITED

Allen, K.R., 1951. The Horokiwi stream. A study of a trout population. N.Z. Marine Dept. Fish. Bull. 10: 231 pp.

Allen, R.K., and G.F. Edmunds, Jr. 1959. A revision of the genus *Ephemerella* (Ephemeroptera:Ephemerellidae). I. The subgenus *Timpanoga*. Canadian Entomol. 91: 51-58.

__________ 1961*a*. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). II. 3. The subgenus *Caudatella*. Ann. Entomol. Soc. Amer. 54: 603-612.

__________ 1961*b*. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). III. The subgenus *Attenuatella*. J. Kansas Entomol. Soc. 34: 161-173.

__________ 1961*c*. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). V. The subgenus *Drunella* in North America. Misc. Publications Entomol. Soc. Amer. 3: 147-179.

__________ 1962. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). IV. The subgenus *Dannella*. J. Kansas Entomol. Soc. 35: 333-338.

__________ 1965. A revision of the genus *Ephemerella* (Ephemeroptera: Ephemerellidae). VIII. The subgenus *Ephemerella* in North America. Misc. Publications Entomol. Soc. Amer. 4: 244-282.

Armitage, K.B. 1958. Ecology of the riffle insects of the Firehole River, Wyoming. Ecology 39: 571-580.

Atlas of Canada. 1957. Dept. of Mines and Tech. Surveys, Geographical Branch, Ottawa.

Bachman, R.W. 1958. The ecology of four north Idaho trout streams with reference to the influence of forest road construction. Master's

Thesis, Univ. Idaho. 97 pp.

Brinck, P. 1949. Studies on Swedish stoneflies. Opusc. Entomol. Suppl., 11: 250 pp.

Clemens, W.A. 1922. A parthenogenetic mayfly (*Ameletus ludens* Needham). Canad. Entomol. 56: 77-78.

Clifford, H.F. 1966*a*. The ecology of invertebrates in an intermittent stream. Invest. Indiana Lakes and Streams. 7: 57-98.

__________ 1966*b*. Some limnological characteristics of six Ozark streams. Missouri Dept. Conserv., Div. Fish., D-J Series No. 4, 55 pp.

__________ 1969. Limnological features of a northern brown-water stream, with special reference to the life histories of the aquatic insects. Amer. Midland Natur. 82: 578-597.

Currie, D.V. 1969. Hydrogeology of Tri-Creek Basin, Alberta. M.Sc. Thesis, Univ. of Alberta, Edmonton, Alberta. 116 pp.

Edmunds, G.F., Jr. 1957. On the life history of *Parameletus columbiae* McDunnough (Ephemeroptera). Utah Acad. Sci., Proc., 34: 25-27.

Edmunds, G.F., Jr. 1959. Subgeneric groups within the mayfly genus *Ephemerella* (Ephemeroptera:Ephemerellidae). Ann. Entomol. Soc. Amer. 52: 543-547.

__________ and R.K. Allen. 1964. The Rocky Mountain species of *Epeorus (Iron)* Eaton (Ephemeroptera:Heptageniidae). J. Kansas Entomol. Soc. 37: 275-288.

Gaufin, A.R. 1959. Production of bottom fauna in the Provo River, Utah. Iowa State Coll. J. of Sci. 33: 395-419.

Gray, J.R.A. and J.M. Edington. 1969. Effect of woodland clearance on stream temperature. J. Fish. Res. Bd. Canada. 26: 399-403.

Hartland-Rowe, R. 1964. Factors influencing the life histories of some stream insects of Alberta. Verh. int. Verein. Limnol. 15: 917-925.

Helson, G.A.H. 1934. The bionomics and anatomy of *Stenoperla prasina* (Newman). Trans. R. Soc. New Zealand. Vol. 64.

Hornbeck, J.W. and K.G. Reinhart. 1964. Water quality and soil erosion as affected by logging in steep terrain. J. Soil Water Conserv. 19: 23-27.

Hynes, H.B.N. 1961. The invertebrate fauna of a Welsh mountain stream. Arch. Hydrobiol. 57: 344-388.

__________ 1964. Some Australian Plecopteran nymphs. Verh. 3, int. Symp. über Plecopteran. Limnol. Schrif. 34/35: 17-22.

Illies, J. 1952. Die Mölle. Faunistisch-ökologische Untersuchungen an einem Forrellenbach im Lipper Bergland. Arch. Hydrobiol. 46: 424-612.

Jewett, S.G., Jr. 1959. The stoneflies (Plecoptera) of the Pacific Northwest. College Press Oregon State, Corvallis, 95 pp.

Jónasson, P.M. 1955. The efficiency of sieving techniques for sampling freshwater bottom fauna. Oikos 6: 183-207.

Kraft, G.F. 1964. Seasonal occurrence and distribution of aquatic insects in Berry Creek. Ph.D. Thesis, Oregon State Univ. (Libr. Congr. Card No. 64-7423) 122 pp. Univ. Microfilms, Ann Arbor, Michigan.

Krygier, J.T. and G.W. Brown. 1967. Water temperature in small mountain streams. J. Soil Water Conserv. 22: 242-244.

Lehmkuhl, D.M. 1968. Observations on the life histories of four species of *Epeorus* in western Oregon. Pan. Pacific Entomol. 44: 129-137.

Leonard, J.W. 1939. Comments on the adequacy of accepted stream bottom sampling technique. Tran. N.Amer. Wildl. Conf. 4: 288-295.

Li, J.C.R. 1964. Statistical Inference. Edwards Brothers, Inc., Ann Arbor. 658 pp.

Macan, T.T. 1957*a*. The Ephemeroptera of a stony stream. J. Anim. Ecol. 26: 317-342.

__________ 1957*b*. The life histories and migrations of the Ephemeroptera in a stony stream. Trans. Soc. British Entomol. 12: 129-156.

__________ 1958*a*. Methods of sampling the bottom fauna in stony streams. Mitt. int. Ver. Limnol. 8: 1-21.

__________ 1958*b*. The temperature of a small stony stream. Hydrobiologia 12: 89-106.

__________ 1965. The fauna in the vegetation of a moorland fish pond. Arch. Hydrobiol. 61: 273-310.

Maciolek, J.A. and P.R. Needham. 1952. Ecological effects of winter conditions on trout foods in Convict Creek, 1951. Trans. Amer. Fish. Soc. 81: 202-217.

Mackereth, J.C. 1957. Notes on the Plecoptera from a stony stream. J. Anim.Ecol. 26: 343-351.

Miller, A. 1939. The egg and early development of the stonefly, *Pteronarcys proteus* Newman (Plecoptera). Morph. 64: 555-605.

Moss, E.H. 1955. The vegetation of Alberta. The Botanical Review 31: 493-567.

Needham, J.G., Traver, J.R., and Y. Hsu. 1935. The biology of mayflies. Comstock Publishing Co., Ithaca. 759 pp.

Needham, J.G., and R.L. Usinger. 1956. Variability in the microfauna of a single riffle in Prosser Creek, California, as indicated by

the Surber sampler. Hilgardia 24: 383-410.

Pennak, R.W. 1953. Freshwater invertebrates of the United States. Ronald Press Co., New York. 769 pp.

Peters, W.L. and L.O. Warren. 1966. Seasonal distribution of adult Ephemeroptera in northwestern Arkansas. J. Kansas Entomol. Soc. 39: 396-401.

Pleskot, G. 1962. Beobachtungen über Diapausen in der Entwicklung der Ephemeropteran. Verh. XI, int. Kongr. Entomol. 3: 363-366.

Reid, G.K. 1961. Ecology of inland waters and estuaries. Reinhold, New York. 373 pp.

Ricker, W.E. 1943. Stoneflies of southwestern British Columbia. Indiana Univ. Publ., Sci. Ser. No. 12, 145 pp.

__________ 1964. Distribution of Canadian Stoneflies. Verh. 3, int. Symp. über Plecopteran, Limnol. Schrif. 34/35: 50-71.

Robertson, M.R. 1967. Certain limnological characteristics of the La Biche and Wandering Rivers. M.Sc. Thesis, Univ. of Alberta, Edmonton, Alberta. 74 pp.

Sailer, R.I. 1950. A thermophobic insect. Science 112: 743.

Sheldon, A.L. and S. Jewett. 1966. Stonefly emergence in a Sierra Nevada stream. Pan. Pacific Entomol. 43: 1-8.

Svensson, P. 1966. Growth of nymphs of stream living stoneflies (Plecoptera) in northern Sweden. Oikos 17: 197-206.

Tebo, L.B., Jr. 1955. Effects of siltation, resulting from improper logging, on the bottom fauna of a small trout stream in the southern Appalachians. Prog. Fish Cult. 17: 64-70.

__________ 1957. Effects of siltation on trout streams. Soc. of Amer. Foresters, Proc., 1956 Meeting, pp. 198-202.

Tebo, L.B. and W.W. Hassler. 1961. Seasonal abundance of aquatic insects in western North Carolina trout streams. J. Elisha Mitchell Sci. Soc. 77: 249-259.

Usinger, R.L. 1963. Aquatic Insects of California. University of California Press. Berkeley and Los Angeles. 507 pp.

Ward, H.B. and G.C. Whipple. 1959. Fresh-Water Biology. Second Edition. Edited by W.T. Edmundson. John Wiley and Sons, Inc., New York. 1248 pp.

Welch, P.S. 1948. Limnological Methods. McGraw-Hill Co., New York. 381 pp.

Whitney, R.J. 1939. The thermal resistance of mayfly nymphs from ponds and streams. J. Exp. Biol. 16: 363-373.

Wustenberg, D.W. 1954. A preliminary survey of controlled logging on a trout stream in the H.J. Andrews Experimental Forest. Master's Thesis, Oregon St. Coll., 51 pp.

APPENDIX I : Results of water sample analyses, Wampus Creek, May 1967 to June 1968

	1967								1968			
Date	5-26	6-15	7-6	8-9	9-15	10-14	11-18	12-15	2-24	4-5	5-8	6-11
Dissolved oxygen (ppm)	11.2	9.2	8.6	10.0	9.8	10.4	11.0	11.2	11.0	11.6	11.4	9.2
Dissolved oxygen (% saturation)	90	85	80	95	90	87	90	90	90	95	90	85
Total alkalinity (ppm $CaCO_3$)	156	137	103	120	160	80	90	90	160	180	70	80
Hardness (ppm)	51	-	-	90	140	140	140	170	170	150	50	70
pH	8.0	7.5	8.0	7.8	8.2	8.4	8.5	8.6	8.3	8.2	7.7	8.4
Total phosphate (ppm)	-	-	-	0.1	0.2	0.1	0.2	0.2	0.2	0.4	0.2	0.2
Sulphate (ppm)	-	-	-	<5	5	<5	5	5	9	10	-	-
Turbidity (Jackson Units)	-	-	-	28	0	0	0	0	0	0	30	10

APPENDIX II : Number of Ephemeroptera caught with regular meshed dip net on each sampling date. Numbers in brackets indicate composition of the group in question expressed as a percentage of total number of Ephemeroptera

	1967								1968			
Species / Date	6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	2-24	4-5	5-6	6-6
Ameletus spp.	33 (2)	54	80 (4)	480 (26)	26 (2)	67 (4)	51 (5)	-	26 (6)	-	12	10
Cinygmula spp.	885 (53)	957 (27)	543 (26)	303 (16)	699 (49)	1137 (63)	880 (80)	-	281 (70)	277 (64)	670 (67)	358 (47)
Epeorus longimanus	27	225 (6)	201 (10)	118 (6)	21	6	-	-	8 (2)	6	20 (2)	45 (6)
Epeorus (Ironodes) sp.	-	-	-	-	4	-	-	-	-	-	-	-
Rhithrogena spp.	2	3	-	3	37 (2)	45 (2)	22 (2)	-	13 (3)	36 (8)	30 (3)	15 (2)
Baetis sp.	705 (42)	2257 (63)	1112 (53)	781 (42)	387 (27)	456 (25)	75 (7)	-	45 (11)	89 (21)	206 (21)	244 (32)
Paraleptophlebia spp.	1	2	-	6	7	5	-	-	14 (3)	1	-	6
Ephemerella doddsi	8	39	134 (6)	114 (6)	199 (14)	71 (4)	60 (5)	-	9 (2)	16 (4)	32 (3)	43 (6)
Ephemerella coloradensis	3	12	4	-	-	-	-	-	4	1	3	18 (2)
Ephemerella grandis ingens	-	3	-	19	28 (2)	5	3	-	-	-	-	3
Ephemerella inermis	-	5	-	4	17	11	7	-	2	5	25 (2)	27 (4)
Ephemerella tibialis	-	-	20	12	-	-	-	-	-	-	-	-
TOTAL	1664	3557	2694	1840	1425	1803	1098	-	402	431	998	769

APPENDIX III : Number of Ephemeroptera caught with fine meshed dip net on each sampling date. Numbers in brackets indicate composition of the group in question expressed as a percentage of the total number of Ephemeroptera

Species	Date	1967 6-15	7-6	7-24	8-18	9-12	10-14	11-18	12-15	1968 2-24	4-5	5-6	6-6
Ameletus spp.		20	41	79 (6)	254 (14)	134 (4)	65 (2)	77 (5)	97 (22)	22 (15)	11	9	29 (2)
Cinygmula spp.		661 (38)	884 (24)	172 (13)	291 (16)	1141 (32)	1313 (48)	1085 (72)	216 (48)	75 (53)	1204 (70)	563 (60)	611 (49)
Epeorus longimanus		235 (13)	239 (7)	229 (17)	91 (5)	15	7	-	11 (2)	18 (13)	36 (2)	12	22
Epeorus (Ironodes) sp.		2	-	-	-	-	-	-	-	-	-	6	-
Rhithrogena spp.		-	2	-	4	18	34	18	7	-	31 (2)	49 (5)	14
Baetis sp.		825 (47)	2403 (66)	576 (45)	956 (54)	1972 (56)	1199 (44)	257 (17)	46 (10)	6 (4)	361 (21)	248 (26)	483 (39)
Paraleptophlebia spp.		1	-	1	4	5	-	2	32 (7)	9 (6)	43 (3)	4	20
Ephemerella doddsi		11	55 (2)	211 (16)	159 (9)	192 (5)	100 (4)	44 (3)	13 (3)	8 (6)	10	24 (2)	31 (2)
Ephemerella coloradensis		4	13	4	-	-	-	1	-	1	5	7	16
Ephemerella grandis ingens		-	-	7	18	16	7	8	2	-	-	-	2
Ephemerella inermis		-	5	-	-	32	6	9	24 (5)	3 (2)	14	14	15
Ephemerella tibialis		-	-	8	9	-	-	-	-	-	-	-	-
	TOTAL	1759	3642	1282	1786	3525	2731	1501	448	142	1715	936	1243

APPENDIX IV : Number of Plecoptera caught with regular meshed dip net on each sampling date. Numbers in brackets indicate composition of the group in question expressed as a percentage of total number of Plecoptera

Species	Date	1967 6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	1968 2-24	4-5	5-6	6-6
Nemoura oregonensis		1	27 (20)	49 (21)	34 (19)	30 (10)	63 (7)	16 (7)	-	6 (4)	8 (4)	31 (8)	62 (15)
Nemoura cinctipes		-	34 (25)	70 (30)	43 (24)	49 (16)	280 (31)	67 (28)	-	22 (14)	147 (44)	19 (5)	30 (7)
Nemoura decepta		24 (14)	1	-	-	-	-	-	-	-	-	13 (3)	86 (21)
Paraleuctra spp.		1	3 (2)	-	-	1	6	-	-	-	3	-	-
Capnia spp.		-	-	-	1	-	-	-	-	73 (46)	-	-	14 (3)
Brachyptera nigripennis		79 (45)	-	-	6 (3)	17 (6)	382 (42)	53 (22)	-	16 (10)	74 (22)	253 (65)	135 (33)
Arcynopteryx (Megarcys) sp.		-	-	-	2	1	1	1	-	-	-	-	-
Arcynopteryx (Skwala) curvata		-	-	-	4 (2)	75 (25)	31 (3)	8 (3)	-	2	1	-	-
Isogenus nonus		50 (28)	13 (10)	8 (3)	17 (9)	10 (3)	39 (4)	11 (4)	-	-	32 (9)	24 (6)	14 (3)
Isoperla spp.		2	-	-	9 (5)	3	23 (2)	1	-	-	2	8 (2)	1
Alloperla spp.		16 (9)	30 (22)	72 (31)	46 (26)	85 (28)	53 (6)	72 (30)	-	24 (15)	36 (11)	20 (5)	44 (11)
Acroneuria pacifica		4 (2)	26 (19)	36 (15)	18 (10)	33 (11)	39 (4)	13 (5)	-	14 (9)	34 (10)	20 (5)	26 (6)
	TOTAL	177	134	235	180	304	917	242	-	157	337	388	412

APPENDIX V : Number of Plecoptera caught with fine meshed dip net on each sampling date. Numbers in brackets indicate composition of the group in question expressed as a percentage of total number of Plecoptera

Species / Date	1967 6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	1968 2-24	4-5	5-6	6-6
Nemoura oregonensis	3 (2)	58 (19)	58 (22)	19 (7)	42 (4)	67 (7)	10 (2)	6 (8)	- -	14 (3)	51 (11)	54 (12)
Nemoura cinctipes	1	39 (13)	61 (23)	55 (21)	148 (16)	162 (17)	41 (10)	14 (19)	16 (15)	35 (8)	28 (6)	48 (11)
Nemoura decepta	60 (31)	-	-	-	-	-	-	-	12 (11)	105 (25)	52 (11)	89 (20)
Paraleuctra spp.	5 (3)	26 (9)	-	-	4	5	-	7 (9)	-	-	-	15 (13)
Capnia spp.	8 (4)	-	-	-	-	-	-	-	11 (10)	29 (7)	32 (7)	16 (4)
Brachyptera nigripennis	54 (28)	-	-	15 (6)	303 (33)	457 (49)	272 (64)	-	14 (13)	56 (13)	234 (49)	96 (22)
Arcynopteryx (Megarcys) spp.	-	-	-	1	3	1	-	-	-	-	-	-
Arcynopteryx (Skwala) curvata	-	-	-	13 (5)	53 (6)	22 (2)	7 (2)	4 (5)	-	1	2	-
Isogenus nonus	19 (10)	39 (13)	2	14 (5)	159 (17)	63 (7)	24 (6)	1	5 (5)	46 (11)	15 (3)	14 (3)
Isoperla spp.	-	-	-	3	7	18	1	-	-	1	1	-
Alloperla spp.	32 (17)	106 (35)	112 (42)	96 (36)	139 (15)	89 (10)	52 (12)	24 (32)	36 (33)	51 (12)	33 (6)	68 (15)
Acroneuria pacifica	11 (6)	32 (11)	33 (12)	49 (18)	66 (7)	43 (5)	19 (4)	19 (25)	15 (14)	85 (20)	32 (6)	43 (10)
TOTAL	193	300	266	265	924	927	426	75	109	423	480	443

APPENDIX VI : Volume-biomass (cc) of Ephemeroptera caught with regular meshed dip net on each sampling date. Numbers in brackets indicate volume of the group in question expressed as a percentage of the total volume-biomass of Ephemeroptera

Species	Date	1967 6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	1968 2-42	4-5	5-6	6-6
Ameletus spp.		0.34 (8)	0.07	0.52 (5)	1.06 (18)	0.14 (5)	0.32 (6)	0.37 (12)	-	-	-	-	0.24 (6)
Cinygmula spp.		2.05 (46)	2.74 (25)	2.43 (26)	2.06 (34)	0.66 (26)	2.80 (54)	1.84 (59)	-	0.14 (70)	0.18 (20)	1.10 (44)	1.03 (24)
Epeorus longimanus		-	0.88 (8)	1.56 (16)	0.67 (11)	0.24 (9)	0.12 (2)	-	-	-	-	-	0.01
Epeorus (Ironodes) sp.		-	-	-	-	-	-	-	-	-	-	-	-
Rhithrogena sp.		-	0.10	-	-	0.05 (2)	0.46 (9)	0.21 (7)	-	-	0.48 (53)	0.54 (22)	0.96 (22)
Baetis sp.		1.79 (40)	4.34 (39)	3.30 (35)	2.00 (33)	0.90 (35)	0.43 (8)	0.05 (2)	-	-	0.04 (4)	0.36 (14)	1.03 (24)
Paraleptophlebia spp.		-	-	-	-	-	-	-	-	-	-	-	0.01
Ephemerella doddsi		0.31 (7)	2.71 (24)	1.63 (17)	0.17 (3)	0.54 (21)	0.92 (18)	0.51 (16)	-	0.06 (30)	0.20 (22)	0.46 (18)	0.94 (22)
Ephemerella coloradensis		-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella grandis ingens		-	0.25	-	-	0.05	0.10	0.14	-	-	-	-	-
Ephemerella inermis		-	-	-	-	-	-	-	-	-	-	0.02	0.05
Ephemerella tibialis		-	-	0.04	0.06	-	-	-	-	-	-	-	-
	TOTAL	4.49	11.09	9.48	6.02	2.58	5.15	3.12	-	0.20	0.90	2.48	4.27

APPENDIX VII : Volume-biomass (cc) of Ephemeroptera caught with fine meshed dip net on each sampling date. Numbers in brackets indicate volume of the group in question expressed as a percentage of the total volume-biomass of Ephemeroptera

	1967								1968			
Species Date	6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	2-24	4-5	5-6	6-6
Ameletus spp.	0.29 (13)	0.20 (2)	0.18 (5)	0.61 (11)	0.52 (18)	0.32 (8)	0.64 (26)	0.26 (31)	-	0.08 (7)	-	0.24 (6)
Cinygmula spp.	0.44 (20)	2.66 (20)	1.02 (27)	2.18 (41)	0.68 (24)	1.98 (47)	0.94 (38)	0.32 (38)	0.08 (62)	0.44 (40)	0.70 (27)	1.03 (24)
Epeorus longimanus	-	0.89 (7)	0.97 (26)	0.34 (6)	0.10 (4)	0.08 (2)	-	-	-	-	-	0.01
Epeorus (Ironodes) sp.	0.04 (2)	-	-	-	-	-	-	-	-	-	0.12 (5)	-
Rhithrogena spp.	-	0.13	-	-	0.05 (2)	0.36 (9)	0.22 (9)	0.10 (12)	-	0.40 (37)	1.10 (42)	0.96 (22)
Baetis sp.	1.11 (50)	5.30 (41)	1.16 (31)	1.94 (36)	0.98 (34)	0.81 (19)	0.14 (6)	-	-	0.05 (4)	0.32 (12)	1.03 (24)
Paraleptophlebia spp.	-	-	-	-	-	-	-	0.10 (12)	-	-	-	0.01
Ephemerella doddsi	0.32 (14)	3.77 (29)	0.39 (10)	0.20 (4)	0.51 (18)	0.58 (14)	0.30 (12)	0.06 (7)	0.05 (38)	0.12 (11)	0.36 (14)	0.94 (22)
Ephemerella coloradensis	-	-	-	-	-	-	-	-	-	-	-	-
Ephemerella grandis	-	-	-	0.04	-	0.06	0.26 (10)	0.01	-	-	-	-
Ephemerella inermis	-	-	-	-	-	-	-	-	-	-	-	0.05
Ephemerella tibialis	-	-	0.04	-	-	-	-	-	-	-	-	-
TOTAL	2.20	12.95	3.76	5.31	2.84	4.19	2.50	0.85	0.13	1.09	2.60	4.27

APPENDIX VIII : Volume-biomass (cc) of Plecoptera caught with regular meshed dip net on each sampling date. Numbers in brackets indicate composition of the group in question as a percentage of total volume-biomass of Plecoptera

Species	1967 6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	1968 2-24	4-5	5-6	6-6
Nemoura oregonensis	-	-	0.03	0.02	0.05 (2)	0.16 (4)	0.04 (3)	-	0.03 (5)	0.04 (2)	0.03 (4)	0.03
Nemoura cinctipes	-	-	0.13 (4)	0.08 (3)	0.11 (3)	1.26 (30)	0.40 (34)	-	0.20 (34)	0.20 (9)	-	0.02
Nemoura decepta	-	-	-	-	-	-	-	-	-	-	-	0.09 (4)
Paraleuctra spp.	-	-	-	-	-	-	-	-	-	-	-	-
Capnia spp.	-	-	-	-	-	-	-	-	0.10 (17)	-	-	0.01
Brachyptera nigripennis	0.40 (29)	-	-	-	-	-	-	-	-	0.06 (3)	0.34 (41)	0.38 (17)
Arcynopteryx (Megarcys) spp.	-	-	-	-	-	-	0.06 (5)	-	-	-	-	-
Arcynopteryx (Skwala) curvata	-	-	-	-	0.76 (24)	0.88 (21)	0.32 (28)	-	0.06 (10)	0.11 (5)	0.08 (10)	-
Isogenus nonus	0.27 (19)	0.22 (13)	0.59 (19)	0.23 (9)	-	0.04	-	-	-	0.05 (2)	-	0.07 (3)
Isoperla spp.	-	-	-	-	-	0.04	-	-	-	-	-	-
Alloperla spp.	0.08 (6)	0.28 (16)	0.78 (26)	0.54 (22)	0.43 (13)	0.30 (7)	0.26 (22)	-	0.20 (34)	0.14 (6)	0.03 (4)	0.31 (14)
Acroneuria pacifica	0.64 (46)	1.21 (71)	1.50 (50)	1.62 (65)	1.88 (58)	1.50 (36)	0.08 (7)	-	-	1.60 (73)	0.34 (41)	1.27 (58)
TOTAL	1.39	1.71	3.03	2.49	3.23	4.18	1.16	-	0.59	2.20	0.82	2.18

APPENDIX IX : Volume-biomass (cc) of Plecoptera caught with fine meshed dip net on each sampling date. Numbers in brackets indicate composition of the group in question expressed as a percentage of total volume-biomass of Plecoptera

Species	Date	1967 6-15	7-6	7-29	8-18	9-12	10-14	11-18	12-15	1968 2-24	4-5	5-6	6-6
Nemoura oregonensis		-	-	0.05 (6)	-	0.05 (4)	0.28 (9)	0.02 (2)	0.03 (11)	-	0.06 (5)	-	0.03
Nemoura cinctipes		-	-	0.10 (12)	-	0.12 (9)	0.63 (21)	0.27 (22)	-	0.05 (21)	0.16 (12)	-	0.02
Nemoura decepta		0.07 (5)	-	-	-	-	-	-	-	-	-	-	0.09 (4)
Paraleuctra spp.		-	-	-	-	-	-	-	-	-	-	-	-
Capnia spp.		-	-	-	-	-	-	-	-	0.07 (29)	-	-	0.01
Brachyptera nigripennis		0.23 (17)	-	-	-	-	-	-	-	-	0.05 (4)	0.47 (34)	0.38 (17)
Arcynopteryx (Megarcys) spp.		-	-	-	-	0.12 (9)	0.06 (2)	- (7)	0.02	-	-	-	-
Arcynopteryx (Skwala) curvata		-	-	-	-	0.38 (28)	0.85 (28)	0.16 (13)	0.12 (44)	-	0.08 (6)	0.17 (12)	-
Isogenus nonus		0.05 (4)	0.67 (57)	0.06 (7)	-	0.02	-	-	-	-	0.06 (5)	-	0.07 (3)
Isoperla spp.		-	-	-	-	-	0.04	-	-	-	-	-	-
Alloperla spp.		0.10 (8)	0.27 (23)	0.10 (12)	0.21 (11)	0.28 (20)	0.49 (16)	0.24 (19)	-	0.12 (50)	0.20 (16)	0.11 (8)	0.31 (14)
Acroneuria pacifica		0.87 (66)	0.24 (20)	0.55 (64)	1.64 (89)	0.40 (29)	0.68 (22)	0.56 (45)	0.10 (37)	-	0.66 (52)	0.62 (45)	1.27 (58)
	TOTAL	1.32	1.18	0.86	1.85	1.37	3.03	1.25	0.27	0.24	1.27	1.37	2.18

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